Go to the people,
Live with them,
Learn from them,
Love them

Start with what they know,
Build with what they have

But with the best leaders,
When the work is done,
The task accomplished,
The people will say,
"We have done this ourselves"

—Lao Tsu(China), 700 BC

INTEGRATED WATERSHED MANAGEMENT

A Field Manual for Equitable, Productive and Sustainable Development

RAJESH RAJORA
I A S.

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To my mother,
Sheela
who always was and
will remain
a source of inspiration

Foreword

People and nature are both part of a whole Unfortunately, in our definition of the environment crisis, we often lost sight of this fundamental truth. If a crisis has developed, it was on account of a distortion that had crept into the interrelationship between Man and Nature. Therefore, to set things right, a holistic perspective was needed Much of our work on combating the environment crisis had in the past hinged on attempting technocratic solutions. In Madhya Pradesh, the Rajiv Gandhi Mission on Watershed Management, started by the government in 1994, made paradigm shift in finding the solution to the environmental crisis and in technology but in people It asserted that there could be a way out of the environmental crisis through direct community action engineered and catalysed in an ecologically holistic unit of a watershed

The Mission acknowledged that the crisis of the environment and the problem of livelihood security of the poor were so interconnected that solutions can only be found together. It, therefore, created a labour-intensive strategy for action that addressed poverty issues even as it rebuilt the environment. People were made the key actors through democratically elected watershed committee members for planning and implementing work Government officials were given the role of catalysts and facilitators, providing funds and technology support Jhabua district in western Madhya Pradesh is one place where the programme has gone to scale and its results are now measurable The role shifts were not easy but they did happen And when that has happened the ecological history of region has begun to change The existing experience of this transformation is captured in this book by one of our dynamic young officers, Dr. Rajesh Rajora, who was both a witness to the transformation and a key actor who made it happen in Jhabua.

In Madhya Pradesh, through Rajiv Gandhi Mission on Watershed Management, communities have been involved in the planning, execution, monitoring and evaluation of watershed activities in 31 lakh hectares of land. They have already treated more than 10 lakh hectares of land and started getting benefits of integrated efforts on agro-forestry, silvipastoral practices, horticulture and grassland management It is heartening to see that watershed committees are slowly emerging to fill the vacuum created by the breakdown of traditional institutions for managing common property resources (CPRs)

The book, *Integrated Watershed Management* by Dr Rajesh Rajora is very valuable, covering all important aspects of watershed development which are needed for a proper grounding in watershed management for agencies and people who are involved in it This book is extremely useful as a comprehensive guide it for Project Implementation Agencies (PIAs) and Watershed Development Teams (WDTs) associated with the implementation of watershed development activities. Dr Rajora has brought into this work the experience gained from his close association with actual field level implementation of watershed activities in Jhabua through the Rajiv Gandhi Mission on Watershed Management The District of Jhabua, once known only for recurring droughts, is now a model in postulating a new paradigm of development through watershed management and community action. In fact, in Jhabua, the turn around from desertification was made possible by converting watershed from a 'geo-hydrological unit' to 'peoples development unit'. Now, Dr Rajora can legitimately claim a share in the satisfaction of the success in Jhabua, where the people have started harnessing the benefits of community action in environmental rehabilitation. Every time I visit Jhabua, it confirms me the workability of harmonious co-existence of Nature and Man through a people-centred holistic integrated watershed management approach.

N. Baijendra Kumar
Mission Director
Rajiv Gandhi Mission on Watershed Management
Government of Madhya Pradesh
Bhopal

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Preface

The degradation of environment in the dryland areas is basically attributed to the increa ing biotic pressure on the fragile ecosystems in the absence of adequate investment an appropriate management practices to augment and conserve the land and water resource Population growth and poverty on one hand and the pressure of rising demand from affl ence and consumerism on the other, have been exerting powerful pressure on t ecosystems It is not consumerism in our country alone that exerts pressure on our natur resources, but it is poverty and underdevelopment. The macro-economic policies whic provide inducement to the over-exploitation of natural resources, that is, at a higher ra than the rate of regeneration, are also responsive for denudation of environment.

The breakdown of traditional institutions for managing common property resourc (CPRs) and the failure of new institutions to fill the vacuum have also been responsible f the depletion of natural resources. The traditional community-based institutions have giv place so far to individualised or market-driven exploitation of natural resources witho any regard for adverse externalities of such actions and to numerous official programm for the development of land and water resources which are dependent almost entirely the top-down bureaucracy with very little participation from the village communities.

There is no doubt that lands subjected to erosion constitute the biggest single threat our country's economy For not only do such lands suffer an increasing loss of productiv because of the progressive loss of the fertile topsoil but they also contribute to the loss o great deal of water by way of excessive runoff along denuded slopes. Soil erosion threatened the survival of small and marginal farmers in India. Every year about 12 billi tons of soil is eroded from wastelands and agricultural lands in India The runoff cause great deal of damage by contributing to the causation of floods and premature siltation river-beds, tanks and reservoirs

The extent of degraded wastelands (including degraded forest lands) in the countr of the order of 175 million hectares. The development of wastelands is an import weapon in the country's war against poverty The watershed development programme tremendous potential to render socio-economic justice, attain self-reliance and to ush balanced development. Out of 175 million hectares of degraded or wastelands, even if million hectares of lands could be made productive to generate employment to about 30 million families. With an average income of Rs. 10,000 per hectare, the national income of the country could go up by Rs 1,20,000 crores every year The new assets could further generate self-employment opportunities to nearly equal number of families through various small-scale and cottage industries based on agro-forest produce and service sector

The Rajiv Gandhi Mission on Watershed Development was launched in Madhya Pradesh on 20 August, 1994. The success of ecological restoration and conservation lies in gathering the widespread support of the people who suffer most the consequences of environmental degradation The community was involved in planning, execution, monitoring and evaluation of watershed. Soil and water conservation techniques, surface and groundwater harvesting and management, agro-forestry and silvi-pastoral practices, conservation agronomic practices, dryland horticulture, grassland management, etc , have been integrated into the programme CPR management, joint forestry management (JFM), equity issues and empowerment of women and landless have been meshed with development of watershed. Indigenisation of transferred technologies offer the least-cost and maximum-benefit scenario. The results of integrated watershed management in more than 10 lakh hectares in Madhya Pradesh have shown that the programme has been able to address to the basic problems of the community and nature. Jhabua has pioneered in integrated watershed development. In fact, it has converted watershed from a geohydrological unit to a unit of development and has transferred it from the hands of social scientists to the community A new paradigm of development has been postulated in Jhabua.

The importance of a proper grounding in watershed management for project implementing agencies (PIAs) and multi-disciplinary teams (MDTs) can hardly be over-stressed The project implementors have to play a role of a link, not simply to develop participatory methods, but equally importantly, to empower the rural poor, to contribute to technical change from their own resources and to articulate demands on government services more effectively PIA has to see that participation gets institutionalised and strengthens prospects of development that is more equitable, democratic and appropriate for the rural poor

It is amply clear by now that no programme aiming development and conservation survives for long in the absence of public support and participation The need of the hour is to change top-down elitist programmes and explore ways of empowering communities to become equal partners in conservation and productivity, building on their traditional knowledge and practices, and ensuring their livelihood security Attitudinal changes are required first of all, and they are by far the most time-consuming and complicated It is hoped that this volume will stimulate, at least to some extent, such rethinking in a large and diverse group of people (like researchers, NGOs, soil conservationists, ecologists, development functionaries, etc) involved in watershed management

This book covers all the aspects of watershed development and management which are needed for holistic, integrated and sustainable development It also provides complete information and guidance on the subject. It is mainly aimed to present the material in such a way that it will give those people an overview of the diverse activities of watershed management and the different ways in which they are and might be involved in watershed management activities.

Everything in nature is linked with everything else and is mutually complementary

Watershed programme can cater to the this relationship operating between nature and mankind. This book just tries to bridge the gaps between ecological challenges and human responses.

I am grateful to Mr. N Baijendra Kumar, Director (Rajiv Gandhi Mission on Watershed Development). It means a lot to me that he has taken the pains to read the manuscript and to put to record a word of immense encouragement. I am thankful to Mr. Badal Das (Development Commissioner), Mr R. Parsuram (Secretary, Department of Rural Development), Mr R Gopalkrishnan (Secretary to Chief Minister) and Mr. Iqbal Ahmed (Commissioner, Indore Division) for guiding me through. This book is an outcome of the inspiration and guidance given by Mr Manoj Jhalani (ex-Collector, Jhabua) and Mr Manoj Srivastava (Collector, Jhabua). Mr. Shrivastava has been instrumental in implementation of numerous innovations in watershed programmes I thank Vrikshamitra Mr A.B. Gupta (DFO) and Mr. R K Gupta (Assistant Geohydrologist) for sharing their field experiences on forestry and groundwater respectively. I gratefully acknowledge the contribution of Mr Ashish Mondal and Ms. Jayanthi (Action for Social Advancement), Mr. A B. Pandey (BAIF), Dr H K. Jain (IRCON) and other NGOs working in Jhabua I record my gratefulness for the tireless efforts of Mr Vivek Painter, Mr Vijay Gupta, Mr. Sudhir Kushwaha, Mr. Sunil Saxena and Mr Arif Khan without whom this endeavour would not have been possible I sincerely thank my wife, Sameeta, for her healthy criticism, constructive ideas and constant motivation right from the inception of this book. Her field experiences as a Project Officer (PIA) and DFO (Social Forestry) provided a direct link for me with the field realities Last but not the least, I thank Rawat Publications for considering my efforts worth publishing I feel indebted to the people of Jhabua who confirmed my belief that integrated watershed management could be an ideal tool for equitable, productive and sustainable development

Rajesh Rajora

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2 Faulty agrarian and agronomic practices may lead to deterioration in quality of soil Depletion of topsoil from small farms may push small and marginal farmers into poverty trap

3 Soil erosion is severest on undulated and sloping wastelands

4 Trainloads of inorganic fertilisers are annually dumped in farm lands Besides creating nutrient imbalances, excesses and injudicious use of chemical fertilisers may turn soil infertile.

5 Sheet erosion on agricultural plots is a gradual process Life support topsoil is first to be washed away.

6 Denuded hills and hillocks suffer from rill erosion mainly due to raindrop impact and lateral transport of detached particles.

7 Rills on hillocks and undulated terrain become deep and wide. Over a period of few years gullies are formed.

8 Uncontrolled gullies may turn into ravines, which is a major ecological threat

9,10,11 Land capability classification is not very difficutl to ascertain Even a layman can differentiate the land capabilities and degradation in a watershed area. Different strategies should be adopted for different land classes

12 Interviews may be misleading. But observations about the household and its surroundings help to gather correct information about the socio-economic status.

13 (a, b) Knowledge about the local customs and traditions help in better understanding of the people.

14 House-to-house contact facilitates the building of a bond between the PIA and the villagers

15 Reaching to villagers and their worksite gives a correct idea about their individual and collective occupational problems.

16 Village modelling not only brings out the creativity of the villagers, but is the

best way to break the ice and collect appropriate information about the natural resources and related problems.

17 Active women's participation in PRA exercises add new facet to collected information.

18 Flow diagrams depict inter-relationship among various factors. It also brings out collective analytical understanding.

19 Participatory exercises bring all the factions of the community together on a common platform.

20 Participating in social ceremonies can be an important tool towards community mobilisation.

21 (a, b) Kalajathas are effective means of spreading the spirit of watershed management and involvement of the community.

22 (a, b) Capacity-building, motivational and technical training programmes should be conducted for PIA members at regular intervals. Similarly, exposure visits could inculcate motivation and direction in them.

23 Remote sensing thematic maps provide valuable technical inputs for micro-planning.

24 (a, b) Cultivation provides not only nutrition and income but also assists in protection of soil form erosion

25 Mixed cropping results in continuous and better cover of the land, good protection from the beating action of the rain, almost a complete protection against soil erosion and the assurance of one or more crops to the farmer.

26 Organic manure prepared in NADEP pits check soil erosion by improving infiltration of soil and soil structure.

27 Boulder checks over gullies on agricultural plots stop further extension of gullies and reclaim land

28 Field bunding should be taken as far as possible on contours Boulder reinforcement should be made wherever necessary.

29 (a, b) Staggered and continuous contour trenches are effective means for SWC on hilly terrain. Proper contours should be maintained while digging these trenches

30 (a, b) Contour trenches should be reinforced with vegatative barriers. Hardy species like Jatropha (ratanjot), Prosopis juliflora (vilayati babool), Anona squamosa (sitaphal), etc., can be taken on bunds along the trenches

31 Boulder checkdams are effective in gully control on undulating terrain. When iron-mesh support is provided to them, especially in gullies with high runoff, they are called gabionic structures.

32 Vegetative barriers on wastelands are more cost-effective than physical barriers Agave is recommended in arid and semi-arid areas

33 (a, b) Boulder walls break the velocity of the runoff and with a period of time, when soil is trapped in them, they help in water conservation as well. Vegetative reinforcement provides stability and logitivity

34 (a, b) Earthen embankments on farm ponds depend on the site conditions, edaphic conditions and proposed objectives. Earthen embankments constructed for irrigation should have optimal capacity

35 (a, b) Boulder pitching on earthen embankment given strength to the structure. Cut

spillways are cheap and quite effective to pass on the surplus water after the dam is full.

36 Excavated (dug-out) ponds have a large portion of the water stored below the original ground level. They should be constructed where the land slopes are relatively flat.

37 Nalla bunding reduces the runoff and harvests the water. They are preferable in arid and semi-arid regions with low rainfall and relatively permeable soils

38 (a, b) Gabion structures are semi-permanent structures for water harvesting Local modifications like concrete core wall gate, etc., should be encouraged.

39 (a, b) Permanent water harvesting structures should be constructed at appropriate place and where maximum benefits could be extracted from them

40 At micro-watershed level, SHGs consisting of 5-15 members (especially women groups) can take up nursery raising.

41 Sprinkling of water from cans is recommended in SHG nurseries. Irrigation should be curtailed, atleast two weeks before planting out, to toughen the plants.

42 (a, b) Saplings should be removed from nursery beds when they attain suitable height

43 Vast unutilised and unprotected areas could be developed into grasslands by promoting local available grass variety and necessary protection.

44 Alongwith natural (indigenous) grasses, soil enriching perennial legumes like Stylosynthes hamata should be promoted on grass beds in arid and semi-arid areas

45 (a, b) Availability of fodder in lean season create opportunities for other income-generating activities Fodder storage and processing (silo or hay making) becomes a necessary step.

46 (a, b) Encouraging agro-horticulture and farm-forestry helps in extra-income generation Farm forestry reduces pressure for fuel wood and fodder on CPRs

47 To supplement nutritional requirement of the household, horiculture should be promoted in kitchen-gardens. Women of the household could take care of these gardens

48 In dry and hilly areas, earthen pot can be used as artificial micro-basin for fruit-bearing trees

49 Improvement of native horicultural varieties by bunding and grafting results into increased production of pest resistant, better quality fruits. Such operations can be carried out by the previously trained village volunteers.

50 (a, b) Vegetable cultivation is an easy way for income generation for women groups

51,52,53 Protection and conservation strategies adopted and promoted through organised informal groups, village forest committees/forest protection committees on CPRs and adjoining forest areas are an integral part of watershed management programme.

54 Uncontrolled grazing and large cattle population in a village devastate and degrade gochar lands and CPRs

55 (a, b) Social fencing is an ultimate aim in CPR management Till the time this is achieved, cost-effective cattle proof walls (CPW), with or without vegetative barriers, may be taken up

56 Making most of available water body, pisciculture by organising fishermen

SHGs is one of the many ways to generate additional income.
57 For women SHGs, collection of MFPs in different seasons provides livelihood support.
58 (a, b) Introduction of low-cost, energy-efficient biogas plants and smokeless sigris/chulhas in watershed villages reduce fuelwood pressure on CPRs.
59 Educating the girl child
60 Promoting awareness about health, hygiene and sanitation among women
61 Credit and thrift activites in women SHGs
62 Economic independence through rural industries
63, 64, 65 (a, b) Alternatives for landless
66 The most crucial and difficult aspect in watershed management is maintenance and care after the project period is over. Sustainability can be ensureed by community mobilisation and institution-building.
67 (a, b) Water table readings should be recorded at frequent and regular intervals from benchmark wells. Simple SWC techniques could increase the water table to astonishing levels.
68 Change on cropped area suggests improved productivity.
69 (a, b) Successful regeneration of degraded forest resources is a direct indicator of community mobilisation.
70 The easiest way to evaluate a watershed project is to judge by the change in living standard of families. On completion of watershed project, if even one household resembles the above picture, then there was something grossly wrong with the watershed programme.
71 Grain-bank

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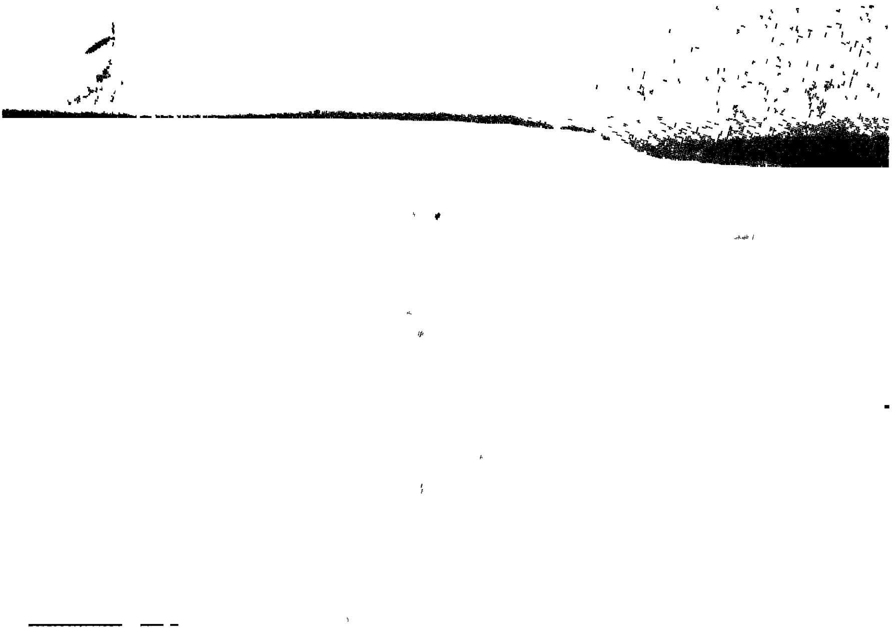
1

Philosophy and Concept of Watershed

What is a watershed? It is a geohydrological unit draining at a common point by a system of streams. All land everywhere is part of some watershed. Essentially, a watershed is all the land and water area which contributes runoff to a common point. It is a land area that captures rainfall and conveys the overland flow and runoff to an outlet in the main flow channel It is a topographically delineated area draining into a single channel (Brooks, 1985). A watershed has a third dimension-height (or depth) The depth of a watershed may extend from the top of the vegetation to the confining geologic strata beneath. Every watershed in the world is as unique as a fingerprint No two watersheds are exactly same. A watershed in alpine region would be very different from dry and dusty watershed of an arid region Two contiguous watersheds, lying side by side, are actually different in detail, even though they may look alike. The watershed above any point on a defined drainage channel can easily be identified. A small watershed of a few hectares draining into a small stream may form part of larger watershed, which in turn may form part of a still larger watershed. All the combined watersheds may become a major river basin draining millions of square kilometres of land The term 'watershed' strictly refers to the divide separating one drainage basin from another But, over the years, the watershed has been identified with drainage basin or catchment area. Watersheds of the small streams are the sub-watersheds of the watershed of the larger stream A watershed may be nearly flat or may include hillocks, hills or mountains Each and every water and land area is a part of one watershed or other The people and animals are part of the watershed community (see Plate 1)

The size of the watershed may vary from a few square metres to thousands of square kilometres The size becomes important, depending upon the objective of the watershed. For example, for large irrigation projects, watersheds of thousands of square kilometres size may be considered On the other hand, for a small storage structure in farm (farm pond), consideration of only a few hectares of watershed suffices Size of the watershed is also affected by afforestation, grassland development, cultivation, etc Many physiographic features like valley, undulating hillocks and rugged hilly tracts influence the size of the watershed. Larger watersheds could be selected in the plains or where afforestation and

Plate 1 *Watershed is a geohydrological unit draining at a common point from a system of streams Area falling under a watershed could easily be seen from top of a hill*



grassland development is the main objective. In the hilly areas of watershed, where agriculture development is the main objective, smaller watersheds are chosen On an average, 5000 ha of milli-watershed is an effective unit of watershed management and 500 ha of micro-watershed is a functional watershed development unit

The above definition, mostly postulated by hydrologists, depicts watershed as a hydrological unit. But, it is beyond doubt that watershed is much more complex In fact, watershed is a biological, physical, economic and social system It is a land mass bounded vertically by the area influenced by human activities, and horizontally by the water that drains into a point in the channel Within this area we have a system consisting of a number of very dynamic and interrelated physical, social and economic factors (Lopez and Hernandez, 1972) From management perspective, a watershed is, in addition to the hydrological characteristics:

— not just an area, but a land mass;

— a point of reference along the main flow channel, with its own particular drainage area

Effect of watershed on the community

A watershed has a wide-ranging effect on the lives of the people at large Soil, water and vegetation are the most vital natural resources and watershed affects all of them The sustained productivity of food, fuel, fodder, forage, fibre, fruit, and small timber can be ensured by judicious and effective management of soil, water and vegetation

(1) *Soil.* The rate and quantity of soil erosion and sedimentation are vital for watershed

community. Accelerated erosion

- — is a system combining very complex, interrelated and spatially and temporally variable natural, social, economic, political and institutional factors;
- — from the economic standpoint, is a productive process (Hufschnridt, 1986);
- — results in loss of land as a natural resource;
- — adversely affects the productivity and production on agricultural, horticultural, forest lands and grasslands,
- — results in higher production and transportation of silt and sediments into the reservoirs which result in the reduction of life and benefits of the reservoir;
- — results in siltation of streams and rivers which cause flash floods;
- — results in severe drought due to low soil infiltration, excessive runoff, etc.;
- — results in converting economic assets into useless commodities by formation of ravines, etc., and
- — results in damage to property

(2) *Water*: Water quality, quantity and regime are influenced by watershed conditions. Runoff

- — results in loss of water from the watershed which could have been used by the community for drinking, domestic use, irrigation, industry, etc ;
- — results in sheet, rill, gully or ravenous erosion of soil from the watershed;
- — leads to decline in groundwater table and affects recharge adversely, and
- — results in damage to property and life

(3) *Vegetation* Vegetation is a very crucial factor which affects erosion, runoff and climatic factors of the area It provides food, fruit, fuel, fodder, forage, small timber, NTFP, etc , to the community It is vital for the human existence

In Jhabua, the Rajiv Gandhi Mission on Watershed Development (RGMWD) has been managed on following objectives.

1 To augment and conserve soil and water (surface/ground) resources as a means of providing sustainable livelihood and reducing vulnerability to droughts
2 To develop an easily accessible repository of scientific and technological inputs for planning and implementation.
3. To maximise people's participation for sustainable resource management.
4 To improve the environmental resource base.

Watershed characteristics

Physiography

(a) *Size*: The size or area of watershed is an important parameter in determining the peak rate of runoff The rate and volume of runoff increases with increase in size of the watershed area

(b) *Shape*: Long and narrow watersheds are likely to have longer time of concentration resulting in lower runoff rates than square shaped watersheds of the same size. The longer it takes water to leave the watershed, the more the opportunity for the water to infiltrate in the soil

(c) *Land slope*: The speed and extent of runoff depends on slope of the land The velocity of flow of the runoff water increases with increase in the land slope. The erosive capacity of runoff varies in direct proportion with the slope of the land on which the runoff occurs. Thus, soil erosion also increases with increase in the land slope The land use is also determined by the slope.

(d) *Drainage density and pattern*· High drainage density watershed drains runoff water rapidly. Drainage pattern is influenced by the slope, lithology, structure, distribution of rock systems, etc. The coarser the drainage texture, the higher the conductivity. In short, erosion hazards are very severe in dendritic and radial drainage patterns and very less in trellis, rectangular and annular drainage patterns (see Figure 1.1)

Edaphic conditions

The soil and geology of the watershed determines the infiltration of water, percolation of water, runoff and soil erosion (see Chapters 2 and 14).

Land use

The land in a watershed has to be used for numerous purposes like cultivation, livestock production, housing, water harvesting, etc. The land use affects rates of runoff, infiltration, and types and quality of vegetation. Suitable land use minimises the soil erosion and reduces the runoff.

Vegetative cover

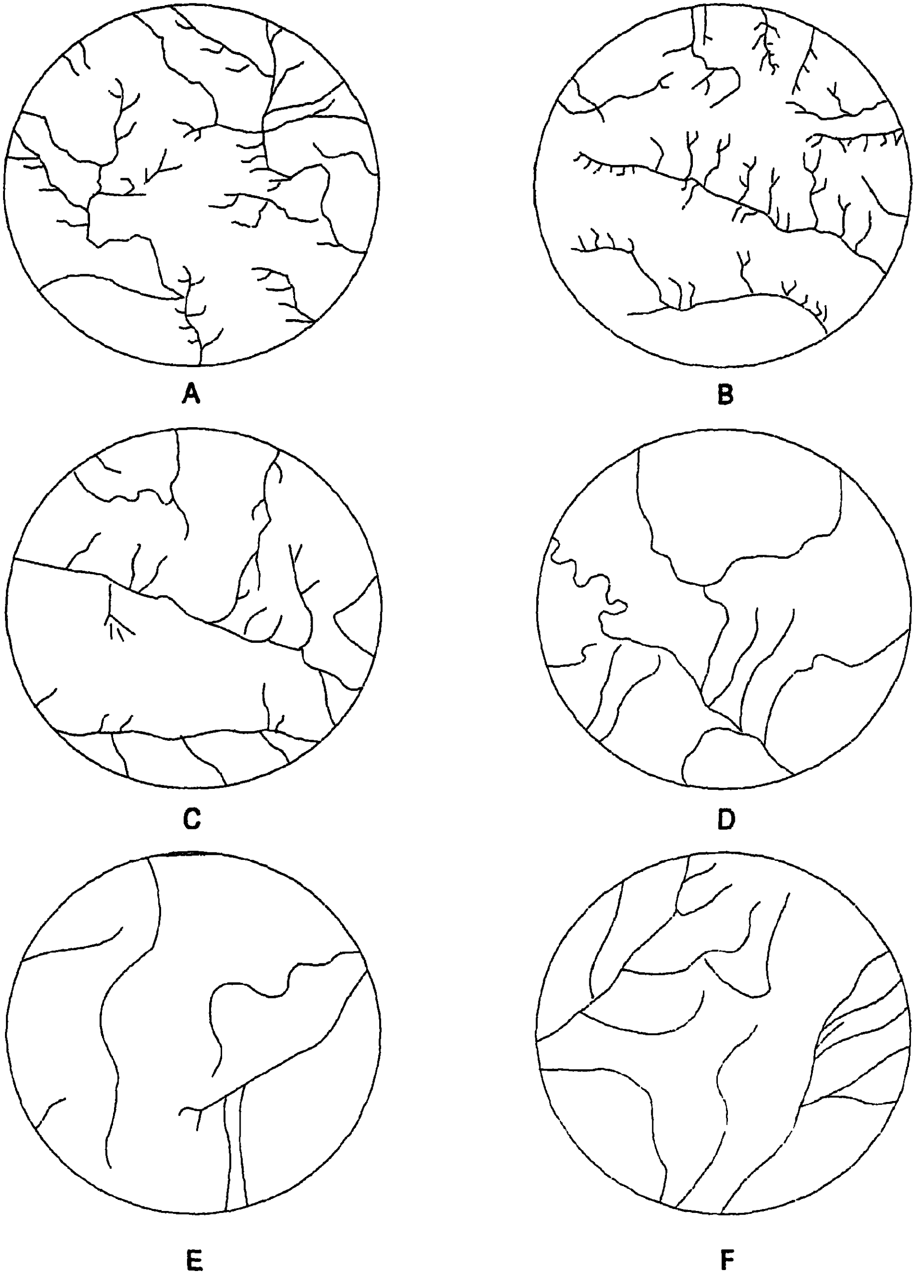
The type, quantity and quality of vegetative cover in watershed influences runoff, erosion and sediment production, rate of evaporation and infiltration rate. The first effect of vegetation is to intercept a portion of the rain through the process of wetting the leaves, branches and stem. In dense vegetation, with three tiers of trees, shrubs and grasses, this intercepted moisture may be substantial. Following the end of precipitation, a portion of this moisture falls to the ground due to wind This delayed precipitation prolongs the period of rainfall at the ground surface, and tends to increase infiltration into the ground. The second influence of vegetation is to protect and shade the soil. Vegetation protects the soil against the impact of direct rainfall through its leaves (which reduce raindrop velocity) and roots (which anchor soil particles). Vegetation has a large effect on infiltration—by shielding the surface from impact, by roots opening channels in the soil for transmission of water, by falling leaves becoming a mulch on the soil surface (an important ingredient for soil-building process) and through the process of transpiration creating moisture deficiency or storage potential. A good cover of vegetation reduces soil erosion and runoff

Rainfall

The amount, frequency and intensity of rainfall determines the behaviour of watershed Evenly dispersed rainfall is less damaging to soil and water than sudden, sharp showers It is possible to generalise in a qualitative way the effect of precipitation variations as follows Other things being equal:

→ Higher precipitation amounts = greater runoff
greater evapotranspiration
greater percolation

Figure 1.1 *Drainage patterns (A & B fine drainage texture, E & F coarse drainage texture)*



→ Higher precipitation intensities = greater runoff
lower evapotranspiration
lower percolation

→ Longer precipitation duration = lower runoff
greater evapotranspiration
greater percolation

→ Greater areal extent of precipitation = greater runoff
greater evapotranspiration
greater percolation
(see Chapter 5)

Socio-economic factors

(a) *Demographic profile.* Total population of the area, sex-age-ethnic group stratification, location and occupation of the population, migration, future demographic trends decide the behavioural characteristics of watershed

(b) *Sociological stratification*: Caste, lineage, families, lines of authority, heterogeneity, political organisation, groupings, social status and political role of individual members, relations between members, spatial distribution of the community and CPR modify the watershed characteristics.

(c) *Farm structure*: Area of farm, number of farm workers, division of labour on farm, collective/individual farming, traditional cropping area, agricultural techniques, land management systems are important factors affecting a watershed.

(d) *Attitudes and behaviour*: Attitudes, aptitudes and behavioural patterns, value systems, belief systems may also play an important role in the performance of the watershed.

(e) *Land tenure systems*: Landholding sizes, dominant classes, landholding classes and castes, methods of land acquisition, alienation of land rights, relationship between land rights and social, political or religious systems, land leasing, sharecropping, marketing system of agricultural produce affect watershed functioning.

Organisational structure

People's participation in watershed operation is a crucial feature which can develop watershed in a holistic and integrated fashion The ideal size of the micro-watershed in which community can be organised effectively, could be between 400-500 ha. The organisation should be capable of integrating backward, forward and vertical linkages Organisations not function efficiently and effectively without community mobilisation. An area of 5000 ha is sufficient, functionally and administratively, for an organisation (PIA), while WDC consisting of representatives of the community could execute and implement the plan at micro-watershed level.

Design peak runoff rate

Peak runoff rate for a watershed has to be estimated as watershed operations and treatments would depend upon it For the design of hydrologic structures, quantitative estimates of peak runoff and volumes should be accurately worked out.

Causes of watershed deterioration

Uncontrolled, unplanned, unscientific land use and interventions lead to deterioration of the watershed area. Some of the activities are:

(1) *Agricultural land.* Cultivation on sloping land without adequate precautions, cultivation without agronomic measures to conserve soil and water, cultivation along susceptible *nalla* banks, cultivation of erosion-permitting crops, overcropping without soil-fertility replenishment, faulty agricultural techniques, etc.

(2) *Grassland*: Excessive and uncontrolled grazing, growth of weeds, development of cattle tracks causing damage and compaction of soil resulting in lower infiltration rates, fires, thefts, etc.

(3) *Forest land*: Excessive and uncontrolled grazing which inhibits regeneration from seed or coppice stock, clear-felling on steep slopes, destruction of forest land by fires and thefts, biotic pressure for fuel, fodder, NTFP and small timber, drastic thinning of plantations along slopes, etc

(4) *Shifting cultivation*: Shifting cultivation or *jhum* cultivation practised in certain areas of the country has proved very damaging to protective and productive vegetation. This practice results in damage to the topsoil and inhibits the growth of grasses, shrubs and trees

(5) *Unscientific mining and construction activities*: These activities damage the vegetation and the landscape The natural drainage lines are often blocked by debris.

(6) *Fire*: Intentional/accidental fires result in loss of vegetation, organic matter and micro-organisms

(7) *Non-cooperation of the community*: Non-cooperation of the community in conserving, protecting and enriching their ecosystem and CPR has also resulted in most of the ills.

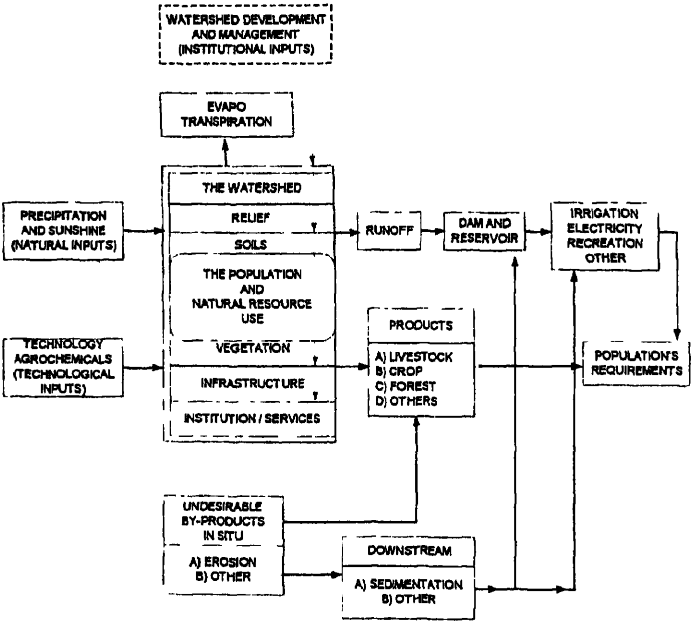
Principles of watershed management

From mid-eighties, development of dryland agriculture on watershed basis has been a national strategy for sustained productivity and rational utilisation of natural resources Thus, the deterioration of natural resources in an area can be contained. The total resource can be properly developed only by adopting the watershed approach The basic unit of development is a watershed, which is a manageable hydrological unit In this approach, development is not confined just to agricultural lands alone, but covers all the areas, starting from the highest point of the area (ridge line) to the outlet of the natural stream In terms of resource development, it covers development and management of resources like soil, water, vegetation and all associated components. By adopting watershed as a unit, different measures are adopted and executed carefully in each of the topo-sequences according to its capability. It essentially relates to soil and water conservation in the watershed which includes proper land use, protection of land against all forms of degradation, building and maintaining soil fertility, water conservation and harvesting, proper management of surface and groundwater, flood protection, sediment reduction, increasing productivity from all land uses, etc

Watershed management may be defined as the process of formulating and carrying out a course of action involving manipulation of natural, agricultural and human resources of a watershed to provide resources that are desired by and suitable to the watershed community, but under the condition that soil and water resources are not adversely affected. Watershed management must consider the social, economic and institutional factors operating within and outside the watershed. Watershed management practices are those changes in land use, vegetative cover and other non-structural and structural actions that are taken on a watershed to achieve watershed development-objectives. Watershed management is an integrated and interdisciplinary approach. It generally requires land use adjustment measures which contribute to the reduction in soil erosion rates *vis-a-vis* increased agricultural production, generation of rural employment and balanced growth of the national economy.

Watershed management usually involves the use, by the people of the watershed area, of the watersheds natural resources, especially the land, water and vegetation, with the active participation of their institutions and organisations and in harmony with the ecosystem. It encompasses and incorporates watershed activities into regional or area development plans, taking into account the protection and conservation measures necessary and the benefits likely to accrue to the people living at the watershed outlet (see Figure 1.2)

Figure 1.2 *Watershed as a system*


WATERSHED DEVELOPMENT AND MANAGEMENT (INSTITUTIONAL INPUTS)
EVAPO TRANSPIRATION
THE WATERSHED
RELIEF
SOILS
THE POPULATION AND NATURAL RESOURCE USE
VEGETATION
INFRASTRUCTURE
INSTITUTION / SERVICES
PRECIPITATION AND SUNSHINE (NATURAL INPUTS)
TECHNOLOGY AGROCHEMICALS (TECHNOLOGICAL INPUTS)
RUNOFF
DAM AND RESERVOIR
IRRIGATION ELECTRICITY RECREATION OTHER
PRODUCTS
A) LIVESTOCK
B) CROP
C) FOREST
D) OTHERS
POPULATION'S REQUIREMENTS
UNDESIRABLE BY-PRODUCTS IN SITU
A) EROSION
B) OTHER
DOWNSTREAM
A) SEDIMENTATION
B) OTHER

The Integrated Watershed Development Programme in drought-prone/desert/non-forest wasteland areas is implemented by taking up projects for development of watersheds of 500 ha each (approximately) in every village in a phased manner The aim of any project or activity comprises of a set of purposes or goals describing the benefits that would flow out of the project, the likely groups of people who would benefit, end result in concrete physical terms that would be achieved by the end of the project, and a set of norms or criteria which are measurable and quantifiable to assess whether the end result has successfully achieved the purposes or not For each such watershed development project, the project objectives, end results and success criteria would be as follows.

Objectives

The objectives of each watershed development project should be.

(i) To promote the economic development of the village community which is directly or indirectly dependent on the watershed through·
  (a) optimum utilisation of the watershed's natural resources like land, water, vegetation, etc , that will mitigate the adverse effects of drought and prevent further ecological degradation, and
  (b) employment generation and development of the human and other economic resources of the village in order to promote savings and other income generation activities.

(ii) To encourage restoration of ecological balance in the village through:
  (a) sustained community action for the operation and maintenance of assets created and further development of the potential of the natural resources in the watershed; and
  (b) simple, easy and affordable technological solutions and institutional arrangements that make use of, and build upon, local technical knowledge and available materials.

(iii) Special emphasis to improve the economic and social conditions of the resource-poor and the disadvantaged sections of the 'watershed community' such as the assetless and the women through
  (a) more equitable distribution of the benefits of land and water resources' development and the consequent biomass production; and
  (b) greater access to income-generating opportunities and focus on their human resource development

Envisaged results

Each watershed development project is expected to achieve the following results by the end of the project period·

(i) All works/activities that are planned for the treatment and development of the drainage lines, arable and non-arable lands in the watershed area and completed with the active participation and contribution of the user groups

(ii) The user groups/panchayats have willingly taken over the operation and maintenance of the assets created and made suitable administrative and financial arrangements for their maintenance and further development.

(iii) All the members of the watershed development committee and staff such as watershed secretary and volunteers have been given orientation and training to improve their knowledge and upgrade technical/management and community organisational skills on withdrawal of the watershed development team from the project

(iv) The village community would have been organised into several homogeneous self-help groups for savings and other income-generation activities which would have achieved sufficient commitment from their members and built up financial resources to be self-sustaining

Success criteria

Although circumstances may greatly vary from project to project, it is important that a few measurable and quantifiable success criteria with the lowest common denominator are fixed for different categories of works/activities under the project to evaluate their success. The success criteria given below are minimal in number and performance standards. The state governments may supplement these with more success criteria if found desirable or prescribe higher performance standards. However, care should be taken to ensure that the additional success criteria are internally consistent with the purposes and end results of the project and also do not conflict with the criteria laid down

The success criteria can be put in two categories. The first category is of such criteria as are specific to each watershed development project. These are essential technical parameters to evaluate watershed treatment/development activities The second type are of general character and would be applicable to all watershed development projects. Each Watershed Development Plan shall fix both types of success criteria These are described as under

(a) Special technical criteria

(i) Qualitative aspects of the works executed, percentage of survival, existence and maintenance of assets created-gully plugs, contour bunds, check-dams, etc.
(ii) Productive aspects—production of usufructs like fodder and grass, fuelwood and minor timber
(iii) Other quantifiable benefits—recharging of wells down stream of the watershed, prevention of soil runoff, effects on increase of soil productivity through increase of biomass and humus in the soil
(iv) Physical and financial targets and milestones throughout the project period
(v) Employment generation targets, minimum wages and labour-material components ratio (60 40) for the watershed as a unit as per the norms under JRY/EAS

(b) General criteria

These deal with performance appraisal in terms of percentage of achievements in works, programmes, community organisation and training.

For project works/activities·

(i) About 80% of the watershed area is covered with treatment or development activities.
(ii) About 80% of the number of project activities/works are implemented through the groups.
(iii) About 80% of the number of works are completed within time and cost estimates
(iv) Wherever local technical knowledge for engineering designs or other technical solutions to specific problems have been identified as appropriate for certain works/activity, around 80% of the number of such works/activities utilise the local solutions straightaway or modify and improve them and then use them in the works/activities
(v) About 80% of the technologies for crop management/afforestation/animal husbandry/horticulture, etc , are adopted by roughly 50% members of the user groups
(vi) About 80% of the completed works on common property resources are taken over for operations and maintenance by the user groups or the community/panchayat.

Selection of watershed villages

The strategy of people's participation for sustainable watershed development is most important. The following criteria are laid down in national guidelines for selecting villages:

(i) Selection shall be made of only those villages from where people's participation is assured. It can be through voluntary donations/contributions in terms of labour, raw materials, cash, etc., for the development activities as well as for the operation and maintenance of the assets created. The minimum norms for such contributions are:
   (a) For investments on community works/development of common property resources (such as pasture lands, social forestry, community nurseries, etc.) on public or private lands, at least 5% of the cost of investment shall be contributed by the community. This may come from the village community/panchayat or users who are likely to derive benefits from these investments.
   (b) For investments on individual works on private property, at least 10% of the value of work/investment must come from the beneficiary/users. However, in the case of scheduled castes and scheduled tribes and persons identified as below poverty line, the minimum contribution shall be 5%
   (c) A resolution from the Gram Panchayat to the effect that the village community/panchayat is willing to take over, operate and maintain the physical assets that will be created as a part of the watershed development project.
   (d) A resolution from the Gram Panchayat to the effect that the Gram Panchayat in the case of common property resources like fisheries tanks, common pasture lands, community forest/wood lots, etc , and the watershed community in the case of other community assets created under the project, shall be willing to share the benefits from these assets with the weaker sections of the society such as those below the poverty line in an equitable manner.

(ii) The receipt of contribution from the community/individuals does not mean that government's investment on the works/activities would go down to that extent. The government shall meet the full cost of the works/activities on 100% basis The public contributions would be acceptable in the form of free labour or materials Where such contributions are received, a sum equal to the monetary value of the free labour and materials would be taken from the Watershed Project Account and deposited in the separate Watershed Development Fund (WDF) in each village for future operations and maintenance of the assets created after the project is over Cash contributions in lieu of free labour or materials shall be directly deposited in the WDF. This fund shall be operated only by the watershed users themselves Preference may be given to those villages.
   (a) where some KRISHI VIGYAN KENDRA (KVK)/other government or private institutions like agricultural university, research agencies, public undertakings, cooperatives, private sector companies/organisations, banks, etc., are working and willing to take on the responsibility of project implementation,
   (b) where the village community has already been successfully organised into homogeneous groups for thrift and credit activity, Development of Women & Children in Rural Areas (DWACRA), social forestry, joint forest management (JFM), community-based convergence of services (CBCS), etc ,
   (c) where other social and community-based campaigns such as literacy campaign, family welfare, prohibition, etc , have been successfully organised in the recent past, and
   (d) where water is allocated on priority basis and other facilities are provided to serve the lands of marginal farmers and women.

Selection of watersheds

In each selected village, a watershed of approximately 500 ha should be identified and selected by the watershed development team in consultation with the panchayat/village community. However should it not be possible to find watersheds of this size, the area can be increased or decreased keeping in view this fact that the PIA handles a total area of 5000 to 6000 ha. The following criteria may be used in the selection of the watershed:

(a) Watershed which has acute shortage of drinking water.
(b) Watershed which has a large population of scheduled castes/scheduled tribes dependent on it.
(c) Watershed which has a preponderance of wastelands.
(d) Watershed which has a preponderance of common lands
(e) Watershed where actual wages are significantly lower than the minimum wages.
(f) Watershed which is contiguous to another watershed which has already been developed/is selected for development.
(g) Watersheds which had been previously taken up for comprehensive development/treatment works under any of the programmes like DPAP/DDP/NWDPRA/IWDP shall not be taken up again. However, if the specific area of the watershed now identified had not previously benefited from any development works, even though it was a part of a larger watershed taken up under any of the programmes, it may be selected for watershed development project
(h) Five hundred ha is a general norm and if on actual survey, a watershed is found to have slightly less or more areas. It may be taken up for development. Even small contiguous watersheds with an approximate total area of 500 ha may be taken up.
(i) Though a watershed should normally fall within the village boundaries, if a small part of the watershed area falls outside the village boundary, it may still be taken up for development with the consent of the neighbouring village/panchayat.

Chart 1.1 *Components of watershed treatment plan (illustrative)*

1 Agronomic measures in agricultural land (e g , strip cropping, crop canopy, residue management, land managment etc.) Chapter 10
2 Mechanical measures in agricultural land (e g , contour and graded bunds, bench terracing, contour cultivation, etc) Chapter 11
3 Erosion control measures for non-agricultural land (e g , contour trenches, gully control measures, *nalla*-bunds etc) Chapter 12
4 Water conservation and harvesting structures (e g , farm ponds, earthen embankments, weirs etc) Chapter 13.
5 Groundwater recharge and management (e g , percolation tank, sub-surface dykes, etc) Chapter 14
6 Nursery raising and community plantation of fuel, fodder,fruit and small timber species Chapter 15
7 Grassland development on recharge, transition and discharge zones. Chapter 16
8 Agroforestry Chapter 17
9 Horticulture development Chapter 18
10 Protection, conservation and enrichment of degraded forest land in watersheds through JFM Chapter 19

Chart 1.2 *Steps in implementation of integrated watershed development programme*

1 Initiation of the watershed programme by selection of watersheds, selection of PIAs, community mobilisation, various tiers of institution-building, capacity-building Chapter 8
2 RRA/PRA excercises in watershed, use of remote sensing in watershed planning, preparation of action plan, entry point activity Chapter 7 and 9
3 Treatment plan execution Chart 1 1 and Chapter 10 to 19
4 Integration of various government programmes
5 Propagation of allied activities and non-farm sector interventions
6 Systems and institutions for CPR management. Chapter 20
7 Schemes and campaigns for empowerment of women, landless and resource-poor. Chapter 21
8 Sustainability of the programme Chapter 22
9 Standardisation of accounting procedures and audit systems Chapter 23
10 Monitoring and evaluation Chapter 24

Salient features of watershed management in Jhabua

1 *Extent of area of operation*: The size of the district is 6.76 lakh ha, out of which 1.24 lakh ha area is being treated on watershed basis Thus, 17% of the total geographical area has been taken up under integrated watershed management Besides, 0 13 lakh ha is under NWDPRA scheme and 0 48 lakh ha has been treated separately by Narmada Valley Development Authority A serious effort in the direction of integrated watershed management in Jhabua has become possible due to the sheer quantum of available opportunities The expanse includes areas with plain or undulating terrain, private or community-owned lands, semi-arid or sub-humid areas This has provided rare opportunity to try and test diverse techniques and modalities.

(2) *Use of remote sensing thematic maps*. Remote-sensing maps on 1:50,000 were procured from Remote Sensing Application Centre, Bhopal. Special attention has been paid on avoiding the programme from becoming too much technocratic. The land use, slope, soil and drainage maps were utilised in selection of villages, and watersheds. In general the maps have been used to accommodate community perceptions scientifically into the action plan In particular, these maps indicated specific locations for cost-intensive and crucial structures like percolation tanks and sub-surface dykes Throughout, the emphasis has been laid on local planning as compared to technical straight jacket panaceas

(3) *Rational utilisation of government organisations and NGOs*. Right from the beginning of the programme since 1994, a rational and pragmatic mix of governmental and non-governmental organisations was considered The huge manpower and technical know-how available with departments like agriculture, forest, soil and water conservation, revenue, irrigation, etc , provided them a headstart Focussed approach and innovative initiatives from NGOs infused dynamism in the programme Out of 17 PIAs in Jhabua, 10 government PIAs were utilised for integration of government programmes and simplification of procedures. On the other hand, 7 NGO PIAs proved crucial in capacity-building of the community and the project managers

(4) *Integration of panchayati raj institutions*. Madhya Pradesh was the first state to estab-

lish three-tier panchayati raj institutions (PRIs), viz., Gram Panchayat, Janpad Panchayat and Zilla Panchayat. Realising a virtual conflicting situation between WDC and Gram Panchayats, various strategies were integrated right from the beginning into the organisational structure. It was made mandatory to include 3-4 members of Gram Panchayats into WDC. Gram Sabha and WA were made co-terminus. Gram Panchayats were constructively involved in the planning, implementation and evaluation of the watershed programme

(5) *Provision of full-time staff*: Government officials implemented watershed programmes along with their departmental responsibilities. Each PIA was provided with one range officer, given on deputation to DRDA from forest department. They acted as project coordinators Each PIA was also provided with one community organiser selected on merit by DRDA on contractual basis. Similarly, two project assistants were appointed in each milli-watershed. The salaries, etc., were drawn from the administrative head of the funds allocated to PIA. This provision equipped even government officials with full time dedicated team for watershed management

(6) *Capacity-building*: To reorient and train project teams and to motivate and organise the community, a systematic capacity-building strategy was adopted Project officers, project coordinators, community organisers, MDT members, project assistants, chairmen, secretaries and volunteers of WDC, SHGs, UGs were trained on various aspects of integrated watershed management. In Jhabua 62 district-level training modules on diverse fields like remote sensing, PRA/RRA, community mobilisation, institution-building, SWC measures, agro-forestry, dryland horticulture, fisheries, dairy, non-farm activities, accounts, monitoring and evaluation, etc., were prepared. Similarly, psychological re-orientation courses were also organised for project officers.

(7) *Watershed as a platform for area development*: Watershed management has been used as a platform for area development. Ideally, watershed could be considered as a new paradigm of rural development. The emphasis on individual growth, community development and nature's enrichment created foundation for successful and effective implementation of numerous government schemes and programmes. Contrary to certain other states where watershed villages have been excluded from other governmental programmes, administration ensured linking benefits from watershed management, both horizontally and vertically The experience has confirmed the opinion that watershed community develops at faster pace and in a well defined direction

(8) *Mission mode*: The Rajiv Gandhi Mission on Watershed Development was launched in 1994. Jhabua also adopted the watershed development programme in a mission mode. The emphasis was on a coordinated, time-bound and multidisciplinary approach in planning, execution and evaluation. All the red-tapes were cut and the mission mode provided zeal and dynamism into the implementation of the programme

(9) *Holistic approach and integration of government programmes* Watershed management is much more multifaceted than mere soil and water conservation NWDPRA was launched a decade back, but has proved ineffective It could not grow beyond SWC measures Watershed management in Jhabua integrated CPR and PPR management with development of agriculture, horticulture, agro-forestry, silvipasture, silviculture, dairy, fisheries, sericulture, non-farm sector activities, etc Rural technology and local wisdom was assimilated selectively Empowerment of women and

weaker sections, equity and sustainability issues were addressed at all steps of planning, execution and monitoring. The holistic and multidimensional aspects of watershed management was achieved by integrating multifarious government schemes like IRDP, TRYSEM, DWCRA, PMRY, *Antyavsayee*, Special Employment Programme, Family Benefit Scheme, Old-Age Pension Scheme, Literacy Programmes, Non-Conventional Energy Programmes, Dairy Development Schemes, DPEP, ICDS, *Kalptaru*, Immunisation and Family Welfare Programmes, GKY, MW Scheme, IAY, Biogas Scheme, etc In Jhabua, all the Rajiv Gandhi missions, viz., on sanitation, control of diarrhoeal diseases, control of iodine-deficiency diseases, fisheries, use of advance technology, ensuring food security, universalisation of primary education and development of rural industries were accommodated and assimilated within the umbrella of Rajiv Gandhi Mission on Watershed Development.

(10) *Topo-sequentiality* Watershed treatment plan was executed according to the topo-sequentiality of the terrain. Jhabua has undulating terrain, so ridge-to-valley treatment strategy was adopted as a thumb rule. This systematic approach has resulted into remarkable achievements and sustainable development

(11) *Flexibility* The programme requires numerous integrations and interventions and envisages decision-making in the hands of the community It is a common practice to over-regulate and over-govern a programme for its effective implementation, which results into rigidity. In such an environ watershed management could not be implemented in its true spirit Thus, a working space for innovations was created, so that community mobilisation and organisation, social auditing, assimilation of rural technology and local wisdom, location-specific interventions, etc , could be possible. This has also resulted in emergence of diverse models of integrated watershed management in Jhabua.

(12) *Joint forest management (JFM) as a vehicle*: Some districts have successfully used literacy campaign, panchayat raj institutions, etc , as a vehicle for launching watershed management programme Jhabua adopted JFM as a vehicle to launch watershed movement Community mobilisation in JFM was utilised to initiate the process. Other aspects like social fencing, regeneration and enrichment of forest resources, CPR management, equity and equitable distribution of benefits, empowerment of community institutions, creation of *gramkosh*, etc , were adopted from JFM Gradually, JFM in watershed areas was merged into the integrated watershed paradigm. JFM and watershed management have been proved as mutually interdependent and harmonious.

(13) *Financial and decision-making powers with the community* As envisaged in the national guidelines, WDC funds were allocated based on the progress to the WDC This created faith in the programme and the community ensured transparency in the expenditures Delegation of financial powers to the WDC and the community acted as a catalyst in mobilising and organising community. All the decision-making powers from planning to evaluation were functionally delegated to WA and WDC

(14) *Community-based convergence of services (CBCS)* Field-level officials of various departments like multipurpose worker (health). *patwari* (revenue), *panchayat-karmi* (panchayat), assistant development extension officer (rural development), *gramsevak* (agriculture), *anganwadi* worker (women and child development or ICDS), handpump mechanic (public health engineering), etc , were trained into various aspects of devel-

opment, health, agriculture, nutrition etc. The interdepartmental rigid boundaries were broken and all the services converged within the community. So the, effectiveness of the services improved.

(15) *Emphasis on grassland development*: On severely degraded wastelands of Jhabua, the process of biomass generation was initiated through production of fodder and foliage in the initial stage. In Jhabua, during 1995-96, Rs. 6 crores worth of grasses were produced while the total expenditure in watershed management programme in that year was only Rs. 2.5 crores. The community got attached to the watershed programme due to instant returns The grasslands developed on degraded forests and wastelands created conditions for reappearance of shrubs and plants and regeneration of trees from root stocks

(16) *Conservation of soil and water*: Watershed projects in other districts prioritised soil conservation or water conservation, depending upon the locality factors. Realising the quantum of soil erosion and extent of runoff, composite soil and water conservation structures in comprehensive and integrated fashion were constructed The results have shown that such composite treatment is more beneficial than staggered erosion control structures or water conservation and harvesting structures

(17) *Emphasis on non-masonry structures* Soil and water conservation scientists and researchers have been propagating cost-intensive and predominantly technical permanent structures. In the field conditions, besides high cost/investment, such structures are more difficult to construct and maintain The efficacy and efficiency of watershed is by no means undermined by construction of low investment, non-masonry structures Masonry and permanent kind of structures were discouraged in Jhabua. Field examples from Gujarat and Maharashtra suggest that very high investments have been made in construction of 5-6 masonry structures in a micro-watershed. In the same cost, most of the area of the watershed could be treated with more equi-distribution of expenditure and benefits Non-masonry semi-permanent structures constructed from local material were recommended and encouraged.

(18) *Emphasis on groundwater management* It is a common observation that even in well-established watersheds, recharge and management of groundwater resources is ignored Surface and groundwater resources should be utilised on a conjunctive and concurrent basis In Jhabua, special attention was given to identify and to recharge and manage groundwater resources Percolation tanks and sub-surface dykes were constructed at most suitable spots in watershed areas

(19) *Gramkosh*· Besides project and development fund, all WDCs in Jhabua opened *Gramkosh* as a third account Voluntary contributions from villages and share of benefits from PPR and CPR were deposited in these accounts The funds available in such *Gramkosh* may be used by the community for any purpose which they feel as essential for the development and welfare Some *Gramkosh* in Jhabua have deposited as much as Rs 3 5 lakhs in last two years

(20) *Promotion of income-generating activities* Poverty alleviation should be an important thrust area in watershed management programme Agriculture, allied activities and non-farm sector activities like village industries have been promoted to improve the income levels

(21) *Empowerment of women and weaker sections* In an effort to maintain equity, weaker

and downtrodden sections like women, SC, ST, landless, etc , have been promoted and encouraged. *Bairani Kuldi* (women credit and thrift groups) and *Anaaj Bank* (Grain Bank) have accelerated the process of equity and women empowerment in Jhabua.

(22) *Emphasis on efficient CPR management*· Village commons were important lands earlier, but with atomisation of the society these commons were either degraded or encroached. CPR are community resources and there development benefits community at large. Enrichment of CPR's through nutrition garden, silviculture/silvipasture, grass production, etc., and their judicious use and management has been of top priority in Jhabua.

Similar or diverse interventions are possible in integrated watershed management No watershed can act as a 'model' so modifications and ramifications should always be undertaken based on locality factors

2

Soils

The soil can be defined as a three-dimensional body, which develops naturally by the action of natural forces acting on natural material and under suitable physical, chemical and biological conditions, and is able to support vegetative growth. The soil is that portion of earth surface which serves as a medium of growth for vegetation. The main constituents of soil are mineral-matter and organic-matter which with the passage of time are permeated by varying amounts of water and air and the soil as a whole serves habitat for organisms It is the unconsolidated mineral-matter that has been subjected to, and influenced by, genetic and environmental factors, parent material, climate, organisms and topography—all acting over a period of time. Soil differs from the parent material in the morphological, physical, chemical and biological properties Also, soils differ among themselves in some or all the properties, depending on the differences in the genetic and environmental factors Thus, some soils are red, some are black, some are deep and some are shallow; and some are coarse-textured and some are fine-textured

Types of rocks

The soil is derived from rocks through the process of weathering and soil formation There are three distinct rock types that are observed in nature They are heterogeneous mixture of minerals and formed by consolidating effects of temperature, pressure, etc

Igneous rocks These rocks are formed during the solidification of a molten magma by fusion of two or more minerals Typical examples of these rocks are granite, basalt, gabbro, and andesite These rocks are composed of primary minerals such as quartz, feldspar, muscovite, biotite, augite and hornblende

Sedimentary rocks Sedimentary rocks produced from the deposition or re-cementation of weathering products Sandstone is a sedimentary rock formed through the consolidation of quartz sand Consolidation of calcareous shells give rise to lime stone and precipitation of hydrous calcium carbonate gives rise to gypsum

Metamorphic rocks These rocks are formed by metamorphosis of other rocks Igneous and sedimentary rocks which have been subjected to tremendous pressure and high temperature have succumbed to metamorphic change. Quartzite is a sandstone impregnated by infiltration of silica

Soils have quartz, orthoclase, plagioclase, muscovite, biotite, chlorite, caluconite, zeolite, clay minerals, amphibole, serpentine, calcite, dolomite, gypsum, hematite, magnetite, etc , in varying amounts.

Weathering of rocks

The rocks suffer the forces of weathering and disintegrate into unconsolidated materials which form the parent material for further development of soil. Weathering is primarily physical in nature in the sense that the effects of physical forces is predominantly demonstrated. The chemical and biological agents also actively change the state of rock and mineral and make it more amenable to soil formation The net result of weathering process is decrease in size of the particles and release of soluble constituents. The mechanical changes that occur through physical forces are due to temperature, erosion and plant and animal influences. The changes that are chemical in nature resulting into decomposition include hydrolysis, hydration, carbonation, oxidation, etc

(a) *Physical process*: Due to variation in the temperature of rocks and air, the rocks experience expansion and contraction. Rocks are nothing but aggregates of minerals which differ in their capacity to expand or contract upon being heated or cooled The result is a kind of shattering rock mass which cracks encouraging break down Ex-foliation of rock mass occurs due to slow heating conduction. The outer surface of the rock is markedly different in temperature than the inner and more protected portion of the rock. This variable heating and cooling renders stress and results into peeling of the surface layers Presence of water in case of freezing conditions enhances the mechanical effects of break down of rock mass The impact of flowing rain water on the horizontal floor along the surface continuously unconsolidates materials of all kinds. The cutting power increases several folds when water contains sediments Example of the cutting power is clearly demonstrated by the gorges, ravines and valleys. The rounding of sand grains on a sea beach is further evidence of abrasion which accompanies movement of water. Ice is cold form of water and exerts tremendous force as weathering agent. The moving glaciers disintegrate rocks and minerals alike The blowing action of wind makes it an important transporting agent When the grains are afloat in the air, the abrasive action of wind increases considerably

(b) *Plant and animal influence.* Simple plants for example mosses and lichens, growing upon exposed rock collect dust on surface along with organic material Higher plants dry the rocks resulting into disintegration This is noticeable in the case of tree roots growing in rocky sections Such influences may be of less importance compared with effects due to other physical factors

(c) *Chemical processes of weathering* Decomposition along with disintegration is noticeable in humid regions where chemical and physical process are particularly active and markedly accelerate each other Following are some of the chemical reactions

(i) Hydrolysis
(ii) Hydration
(iii) Carbonation and other acidic processes
(iv) Oxidation

Factors of soil formation

The soil formation is a complex activity. The soil formation results into creation of soil properties which enable the vegetation to establish and multiply. The factors of soil formation bring about the changes due to their reactions and reciprocal influences. The factors affecting soil formation are as under:

— climate (cl)
— parent material (p)
— relief (r)
— biosphere(b)
— time or age (t)

(a) *Climate*: It acts through regulation of temperature and precipitation. These two factors must remain in favourable combination to produce balanced soils. Precipitation regulates moisture and air regime in the soil Shallow soils result from erosion on steep slopes and deeper soils are encountered downhill due to deposition. The nature, intensity, frequency and distribution of the precipitation determine the impact. Generally, with increase in moisture content of soil, nitrogen, carbon, clay, aggregation, saturation capacity and exchangeable hydrogen tend to increase and exchangeable bases and pH decreases. However, in tropics, increase in the rainfall results in the decrease in clay content possibly because of decomposition. Temperature accelerates the rate of chemical reaction (x2 with every 10 degree rise in temperature) Temperature governs the organic-matter decomposition and the microbial activity. Nitrogen, organic-matter, decrease with increase in temperature. Luxuriant vegetation can be observed in such areas but due to high temperature, accumulation of organic matter is very little Jemmy and Raychaudhari worked out for Indian soils that the nitrogen and carbon content increase with increase in mean annual precipitation in hot coastal regions of India as also in the cool Himalayan regions; but negatively so with mean annual temperature. Thus, compared to coastal regions, soils are richer in organic matter at high elevation

(b) *Parent material*: The weathering of rock continues until all essential elements become available to support lichens and other lower plants As generations of lichens grow, die, and decay, they leave increasing amounts of organic matter. Organic acids further hasten the decay of the rock. With an increasing build-up of organic matter and of fine rock fragments, more rain water is available for use by larger number of plants and animals. With the passage of time, mobile material near the surface will be leached downward and some deposited a few inches below the surface The effect of parent material on soil is stronger in the early stages of soil formation With excessive leaching and advanced development, the influence of parent material on soil characteristics gradually decreases. Igneous rocks and sand stones usually weather slowly and give rise to coarse sandy soils, with low base status, a kaolinite type of clay and infertile soils Most of the basic igneous rocks and sedimentary rocks normally weather to fine-textured soils with high base status, and fertile soils Hard, pure lime stones yield sandy, shallow soils (*terra rossa*), whereas soft lime stones give rise to deeper and fine-textured soils In tropics, due to intense weathering, similar soils may develop from such contrasting parent rocks as basalt, lime stone and granite gneiss

(c) *Relief* Relief affects erosion and moderates the climate and water-air relationship in the soil. With increasing altitude, climate becomes cooler and sometimes more humid.

Relief or the slope also regulates the drainage of the soil Steeper the slope, thinner will be the soil and *vice versa*. In depressions, the runoff is received from the surrounding slopes and the condition favours good vegetation growth but slower decomposition of organic matter resulting into organic matter accumulation. If the surface remains wet for long period of time, a peat or muck soil develops

(d) *Biosphere*· This factor covers the activities of living form of all sizes and shapes including the activities of human beings Vegetation contributes organic matter to the soil which acts as substrate for microbes to bring about host of transformation in the soil. Some localised effects of burrowing animals, e g., rodents, ants, termites and earthworms assume importance in soils where they are found in large numbers and they intermix the soil. Human beings have also been responsible for bringing about changes in the land. Most of the economic pursuits, e.g., tree felling, shifting cultivation, conversion of forests into agricultural lands, etc many a times, result into disturbances in the landscape and soil erodes Some of the cultural practices in the region may also bring about long lasting changes in the soil profiles.

(e) *Time or age*: Generally, differentiation of horizons appear faster under low temperature and high humidity conditions of the forest areas Factors which slow down the soil formation are: low rain fall, low relative humidity, calcareous parent material, excessive sand fraction compared to silt and clay content, resistant parent material, very steep slope, high water table, constant accumulation of soil material by deposition, severe wind or water erosion, large number of burrowing animals, cultural or tillage activities, etc

Soil forming processes

The integrated influence of the different soil forming factors under a set of conditions result in soil forming processes Specific features develop in soil profiles under the influence of these processes. Some fundamental processes involved are·

(a) *Humification* This process helps in the accumulation of surface humus (A-horizon) The humification results from the decomposition of surface debris. The water carries along the organic acids to the lower developing horizons.

(b) *Eluviation and illuviation*: Eluviation means movement of constituents which are washed out of A-horizon and accumulate in B-horizon. The B-horizon accumulates the subsistence through illuviation In brief, eluviation is wash-out and illuviation is wash-in process. These processes are governed by the movement of water. The mechanical eluviation removes finer suspended soil fractions and results into development of textural profile with coarser A-horizon and finer B-horizon Chemical eluviation differentially translocates products of decomposition, e g , organic matter, silicic acid, exchangeable bases, salts, hydrated alumina, and hydrated ferric oxide

(c) *Podzolisation*· This is a type of "wash-out" process in which humus and sesquioxides become mobile and leach from A-horizon and deposit in the lower horizons. This process is accelerated in sandy quartzose and poor parent material in the forest area where leaching is intense Regions where podzolisation is a dominant soil forming process are characterised by low temperature and high humidity forests The process has also been observed in tropical areas where rainfall is enough to cause percolation of water through soil rich in acid organic matter Coniferous areas of country demonstrate podzolisation fairly well.

(d) *Laterisation*: In this process, silica becomes mobile and is removed from horizon-A leaving behind iron and aluminium There are no well-defined horizons. This process is favoured by rapid decomposition of parent rocks under conditions of high temperature and sufficient moisture for intense leaching. This process is frequently observed in humid tropics. The parent material is subject to strong chemical reactions with the release of bases and pure silicic acid and hydrated oxides of iron and aluminium The silica released from silicate minerals becomes mobile and migrates downward leaving behind iron, aluminium and manganese. Similarly, the soil shows low acidity due to accumulation of bases, but with pronounced leaching these bases are lost. Gradually, due to hydrolysis of primary minerals, acidity and other processes may also occur.

(e) *Calcification*: In this process, there is usually an accumulation of calcium carbonate in the soil profile. The soil is well supplied with calcium and base saturation is also high. This process is predominant in temperate regions with low rainfall (less than 25 inches) and in tropics having rainfall of less than 45 inches The soil supports grasses and shrubs. The calcium and magnesium carbonates accumulate due to low rainfall and native vegetation.

The processes of soil formation include (i) the addition of organic and mineral materials, (ii) the loss of these materials from the soil, (iii) the translocation of materials from one point to another within the soil column, and (iv) the transformation of mineral and organic substances within the soil (Plates 2 and 3)

Soil profile

It is a vertical section of the soil through all its horizons and it extends up to the parent material A study of soil profile is important both from the standpoint of soil formation and soil development (pedology) and crop husbandry (edaphology). In deep soils, the soil profile may be studied up to 1.25 m and in others upto the parent material The layers (horizons) in the soil profile which vary in thickness may be distinguished from the morphological characteristics which include colour, texture, structure, etc Generally, the profile consists of three mineral horizons 'A', 'B' and 'C'.

The 'A' horizon may consist of sub-horizons richer in organic matter intimately mixed with mineral matter 'A', the horizon that has lost clay, iron or aluminium with the resultant concentration of quartz (A2-eluvial horizon) or an intermediate or transitional horizon.

The 'B' horizon is below the 'A' horizon showing dominant features of the concentration of clay, iron, aluminium or humus alone or in combination

The 'C' horizon excludes the bedrock from which 'A' and 'B' horizons are presumed to have been formed The 'C' horizon by itself is relatively little affected by pedogenic processes It is the layer of consolidated bedrock which upon weathering, may be presumed to have given rise to the 'C' horizon above

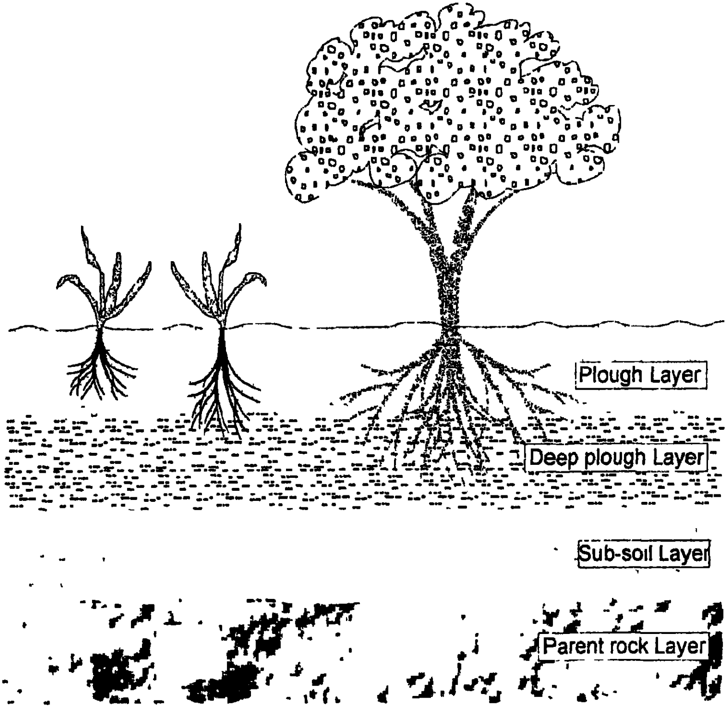
Not all the profiles show the sequence mentioned above. Since the formation of soil and the development of profile are dependent on the genetic and environmental factors which vary considerably within and between regions, variations in horizonation are frequent and common In some forest soils, organic layers may also be found on the surface above 'A' It may be mentioned that a study of morphology of the soil profile gives a clear

Plate 2 *Faulty agrarian and agronomic practices may lead to deterioration in quality of soil Depletion of topsoil from small farms may push small and marginal farmers into poverty trap*

Plate 3 *Soil erosion is severest on undulated and sloping wastelands*

expression of the influences of the pedological processes involved. A study of the soil profile is important since it reveals the surface and the sub-surface characteristics and qualities, namely, depth, texture, structure, drainage conditions and soil-moisture relationships, which directly affect plant growth. Hence, the soil profile is taken as a unit of study which helps the investigators both to classify the soils and to understand soil-moisture-plant relationships (Figure 2.1).

Figure 2.1 *The soil profile*



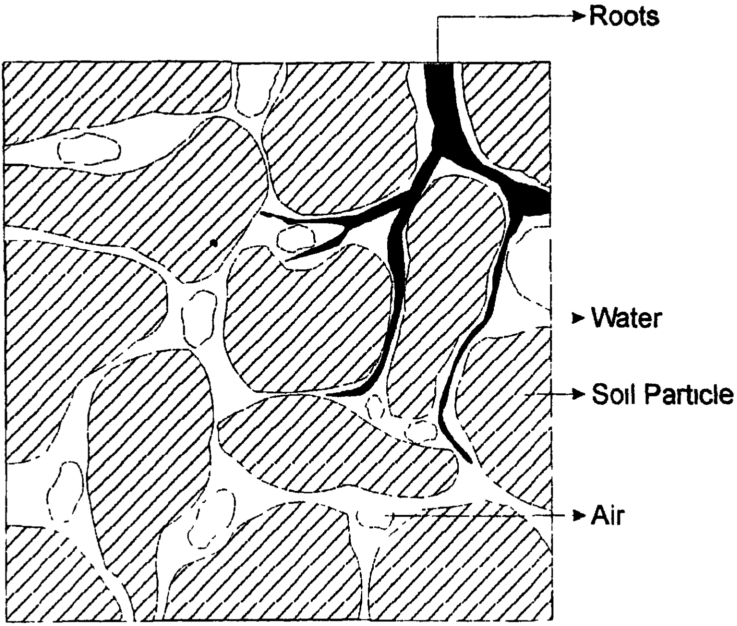
Constituents of soil

The four major components of a typical soil are mineral matter, air, water and organic matter Mineral matter contributes 90% weight of soil

Physically, the soil consists of stones large pebbles, dead twigs, roots, leaves, coarse sand, fine sand, silt, clay and humus The chemical composition will show percent weight loss on ignition, silica and insoluble silicates, iron oxide, alumina, lime (CaO), potash (K_2O), phosphate (P_2O_5), nitrogen (N) and organic matter (Figure 2 2).

The soil separates, viz., sand, silt and clay show minerals of primary and secondary nature. Sand fraction has predominance of quartz, small quantity of primary silicate minerals and other secondary minerals In clay fraction of the soil, most predominant minerals are secondary silicate minerals with a small proportion of oxides of iron and aluminium. The constituents of the soil mass only show the potentiality of the soil to supply nutrients whereas the mineralogical composition of soil separates could reveal much information on

Figure 2.2 *The composition of the soil*



the soil mineralogical potential, the state of development of soil and, to an extent, the physical and chemical state of the soil.

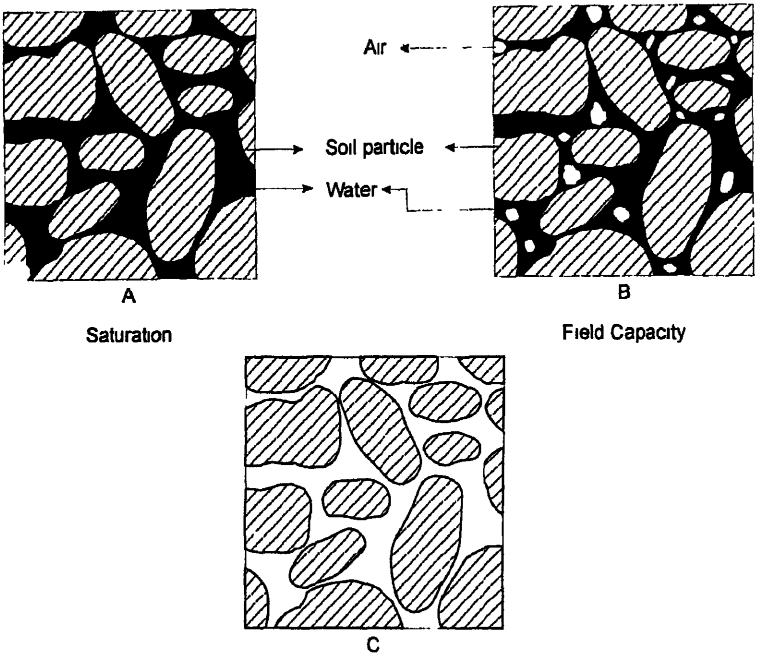
Physical properties of the soil

Since there is always some activity going on in the soil, composition of soil-air and water keeps changing The solid phase in the soil consists primarily mineral matter alongwith some organic matter The presence of solid particles in the soil is always accompanied by associated voids These voids play an extremely important role in determining the physical behaviour of the soil Since the movement of air and water is governed by the presence of these voids, physical behaviour of the soil is dependent upon size of the soil particle, and consequent pore space (measure of voids), arrangement of these particles, extent to which the pores are filled up with water and air, density of soil, colour of the soil and the heat movement in the soil.

Soil texture

Soil mass consists of particles of different size and as soil particle reduces in size, the behaviour of the soil particle gains considerable importance (Figure 2 3) The soil particles after their mechanical analysis can be treated as mechanical separates. These separates have been classified according to range of their size. The particles are considered to be spherical with diameter expressed in millimetres (Table 2 1)

Figure 2.3 *Some soil moisture characteristics*



Saturation

Field Capacity

Permanent Wilting Point

Table 2.1 *Particle size classes*

S No	*Class*	*Diameter range (in mm)*
	International System	
1	Coarse	2 00 to 0 20
2.	Fine sand	0 20 to 0 02
3.	Silt	0 02 to 0 002
	U S D A System	
1	Gravel	2 00
2.	Very coarse sand	2 00-1 00
3.	Coarse sand	1 0-0 2
4	Fine sand	0 2-0 02
5	Silty	0 02-0 002
6	Clay	0 002

Soil structure

Due to various activities of micro-organisms in presence of organic matter, roots, clay, soluble salts, Fe and Ca drying and weighing classes of the soil may resolve into clustering of the particles to form aggregates These soil particles with the help of certain sticky material or cementing material may form soil aggregates. Thus, the mechanism of structure formation induces aggregate formation as well as stability to the aggregates. The arrangement of these soil aggregates in a definite pattern is known as soil structure (see Table 2.2).

Table 2.2 *Composition of soil*

S No	*Class*	*Sand(%)*	*Silt(%)*	*Clay(%)*
1	Loamy sand	85	10	15
2	Sandy loam	65	25	10
3	Loam	45	40	15
4	Silty loam	20	60	20
5	Silty clay loam	15	55	30
6	Clay loam	28	37	35
7	Clav	25	30	45

(a) *Sand* This group includes all soils of which the sand separate makes up more than 70% material by weight. The properties of such soils are, therefore, characteristically sandy in contrast with other soils. Two specific classes are recognised: sand and loamy sand.

(b) *Clays*· The clay must carry atleast 5% of the clay separate. The characteristics of the separates are distinctively dominant and the class name is sandy clay, silty clay or simply clay. It is worth noting that sandy clay often contains more sand than clay Likewise, the silt content of the silty clay usually exists in equal fractions.

(c) *Loams* This group contains many sub-divisions The ideal loam may be defined as a mixture of sand, silt and clay particles which exhibit light and heavy properties in about equal proportions. Roughly, it is a half and half mixture on the basis of the properties The loam possesses desirable quality of both, sand and clay without showing the undesirable properties, such as extreme looseness and low water holding capacity on one hand and stickiness, compactness and slow air and water movement on the other A loam in which sand is dominant is classified as a sandy loam of same kind in the same way there may occur silt loams, silty clay loams and clay loams

(i) *Plate or plate-like structure* The arrangement of aggregates is more in horizontal direction than the vertical direction The shapes are like leaf or lens. When the units are thin, the structure is laminar and platy when the units are thick The soil where platy structure is found suffer from drainage problems

(ii) *Prismatic or prism-like structure* The orientation of aggregates is more towards vertical than horizontal axis Thus, the unit takes shape of columns with round tops or honey-comb tops The units are variable in their size and column diameter may even reach up to 15 cm This structure is usually found in arid and semi-arid areas When the tops are round it is called columnar and when the tops are level or flat or honeycomb, the structure is known as prismatic.

(iii) *Block or block-like structure*· In this structure, the units are oriented both in horizontal as well as vertical axis almost equally The structural units thus assume the shape of a block This structure is usually seen in humid areas and soils with high clay contents.

When the blocks have sharp edges it is known as angular block, and when the edges are blunt or rounded they are known as sub-angular blocks.

(iv) *Spheroidal or sphere-like structure*: In this structure, the air and water circulation is ideal and favours excellent germination and growth of the plant The rounded aggregates may have 1 25 cm diameter. When the spheres of aggregates are relatively less porous, they are called granular and crumb, when they are very porous

Factors affecting soil structure

(a) *Soil management*: The cutting action of ploughs or other tillage implements break the soil mass and may have favourable or adverse effects on the structure, depending on whether the soil is worked under optimum moisture conditions or not Good soil management, with a proper system of crop rotation, has the effect of maintaining the soil in a good state of aggregation.

(b) *Absorbed cations*. Sodium and potassium ions on the clay complex have a tendency to disperse the soil; calcium, on the other hand, has favourable effects on the aggregation. Similarly, the presence of soluble salts favour flocculation.

(c) *Micro-organisms* The filamentous growth of soil fungi and the microbial decomposition products of organic matter have a binding effect on soil particles, thus favouring aggregation. Similarly, the excrements of earthworms and the burrowing activities of insects and other creatures cause appreciable changes in the soil structure.

(d) *Variations of soil moisture*: Variations of soil moisture due to drying and wetting influence the structure. The drying of soil, in general, forms cracks and big clods Poorly drained soils, with excess of moisture, usually have an unfavourable structure

Density of soils

Mass per unit volume of a soil is known as its density. There are two components of soil density, i e , particle density and bulk density

(i) *Particle density*: The particle density refers to the solid portion of the soil and consists of accumulative densities of the individual organic and inorganic soil constituents A particle density of 2.6 to 2 75 g/cc is observed in mineral soils The density of 1 2 to 1.80 g/cc is observed in soil with large quantity of organic matter

(ii) *Bulk density* Often dry mass of a unit volume of a soil inclusive of pore space and expressed as g/cc is called bulk density Bulk density will naturally be less than particle density. A value of 1 7 g/cc is observed in sandy soils and 0.5 g/cc in organic matter

Soil porosity

The volume occupied by voids or pore expressed as percent is called soil porosity The porosity is expressed as percent pore space as below

Percent pore space is equivalent to 100-[(BD/PD) x 100]

where, BD is bulk density (g/cc) and PD is particle density (g/cc)

The pore space increases with the fineness of the soil. There are two types of pores, viz , micro-pores and macro-pores and thus two together govern the air and water movement in the soil Any working with the soil that reduces soil aggregation and decreases the organic matter in the soil decreases pore space too Porosity normally decreases with depth of the soil

Soil consistency

This is the physical condition of a soil at various moisture contents as evident by the behaviour of that soil towards mechanical stresses and manipulations. The consistencies are described as loose, friable, firm, soft, harsh, plastic and sticky.

Swelling and shrinkage

This property is more frequently demonstrated by clay soils. With absorption of moisture there is a increase in volume which is called *swelling*. *Shrinkage* occurs when soil dries up and there is a decrease in soil volume.

Soil colour

The colour sometimes becomes a predominant feature of soil, and soils are known due to their shades and colours, e.g., black, red, yellow, grew soils. The parent matter has influence on the soil colour, e.g., red soils from red sand stone. Organic matter induces darkness to soil, iron from compounds inducesred, brown and yellow tinges and silica, lime and other salts impart, white and grey tinges.

Soil colour can be described by a system developed by Musoil Colour Company, USA. The system incorporates three variables of colours, viz , hue, value, and chroma Hue indicates its relation to red, yellow, green, blue and purple, the value indicates its lightness; and the chroma indicates its strength.

Soil temperature

The primary source of heat in the soil is the sun. Other sources such as the heat liberated during organic matter transformation is less significant. There is a daily movement of heat in the soil. Soil colour, organic matter content, moisture content, etc , influence soil temperature. The temperature regulation of soil is important for favourable physical and chemical properties of the soil.

Soil water relationship

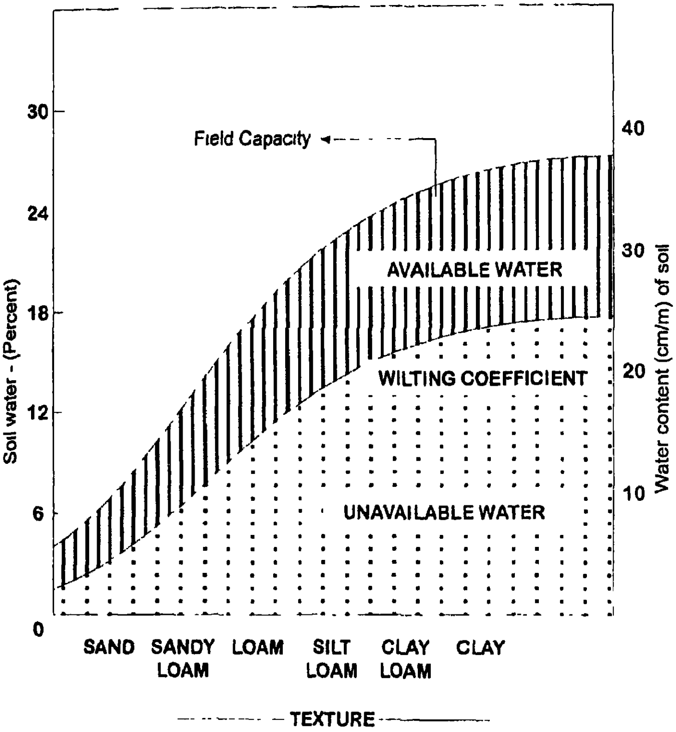
Soil water is one of the most important aspects of the soil-plant relationship. Water plays important functions in photosynthesis, as solvent and carrier for nutrients. The turgidity of the cells is maintained by water

Soil water terminology

Infiltration	Downward entry of water from above ground into the soil.
Percolation	Movement of water through a column of soil generally under saturated or near saturated condition
Permeability	Relative ease of movement of water within the soil

The movement of water into and within the soil is largely governed by the orientation of soil aggregates, e g , platy structure would allow little water as compared to granular structure Water retention by soil is an important attribute for optimum plant growth. The retention of water by soil depends upon movement of water in the soil, moisture storing capacity, available water to plants among all the pores in the soil, etc A soil is said to have attained field capacity when all the water moves down under the influence of gravity, the amount of water held by the soil against this influence would be available to the plants until plants have absorbed as much as to show the wilting and could not absorb any more commensurate with their requirements The amount of water at these two stages is called *available water* (Figure 2 4).

Figure 2.4 *The water in the soil is related to the texture of the soil*



The soil-water, field capacity and wilting coefficient go on increasing with the increase in heaviness or clay content in the soil content in the soil Heavier the soil greater would be the availability of water

Soil water classification

The force with which water is held by the soil can be expressed in atmosphere on the following scale

Atmosphere				
1/3"	15"	31"	1000"	10,000"
Field capacity	Wilting point	Hydroscopic water	Air dry	Oven dry

Measurement of soil moisture

(a) *Gravimetric* This method involves taking a soil sample from the field in a metal box, weighing the box with wet sample, drying the soil sample in an oven at 105 degree centigrade, weighing the box with dry soil sample. The loss of weight will be due to loss of water from the soil sample This loss in weight is expressed as percentage of oven dry weight of the soil

$$\% \text{ moisture} = \frac{\text{Loss in weight}}{\text{Oven dry weight of soil}} \times 100$$

In most cases, moisture is presented on an oven dry basis. The demerits of this method are that, the method is time-consuming, laborious, and involves sampling, weighing and drying.

(b) *Equilibrium tension.* Measurement is based on equilibrating the soil moisture tension with a porous clay cup filled with water representing free water surface. Any loss of water due to either evaporation or due to plant absorption is made good by suction created at the surface of the clay cup The subsequent suction is shown in the manometer connected with the cup through a tube This contravention is known as *tensionmeter*. The tension reading in the vacuum gauge or the manometer can be calibrated to show moisture percentage. One of the demerits is that this device measures low range in the tension. Air bubble if introduced in the tube can render the reading inaccurate. This device is more suited to sandy soils than to heavy-textured soils (Figure 2 5)

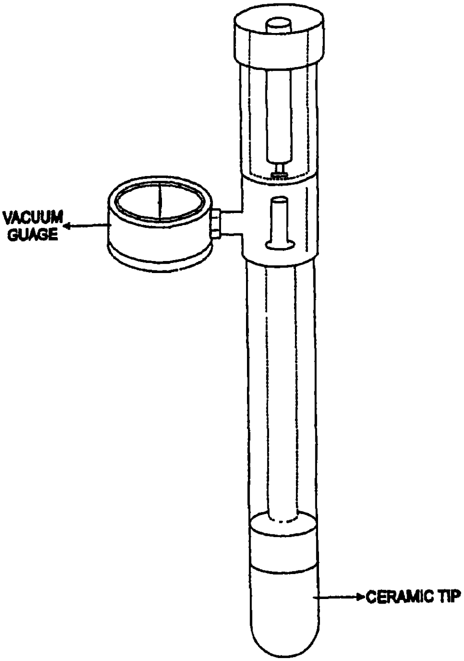
(c) *Pressure plate apparatus*. This is a much improvised version of tension measuring device. It does away with the low range of tensionmeter It can measure the moisture from 1/3rd atm to 15 atm. The demerit of this method is that it is confined to laboratory only Saturated soil samples are kept on porous plate and suction is applied in an air-proof apparatus. The suction is continued till the water is sucked out The reading of the moisture content of the sucked out soil sample is quite accurate and reliable

(d) *Electrical conductivity*· Moisture of the soil can change the electrical conductivity of the soil The change in the electrical conductivity is thus used to measure the moisture content of the soil The electrodes are fixed in a gypsum block mould, the current passing through the electrodes is measured by a modified whetstone bridge The blocks are quite durable and accurate The method is affected by salt status of the soil It is totally unsuited for the soils having high salt content

(e) *Heat conductivity* The heat flow in a soil is also governed by the moisture content of the soil Measurement of heat conductivity can be employed to measure moisture content of soil

Soil moisture content is commonly expressed as the amount of water present in a depth of one metre of soil For example, when an amount of water (in mm of water depth) of 180 mm is present in a depth of one metre of soil, the soil moisture content is 180 mm/m The soil moisture content can also be expressed in the percentage of volume A moisture

Figure 2.5 *Tensiometer*



content of 180 mm/m corresponds to a moisture content of 18 volume percent.

Saturation, field capacity and permanent wilting point

Due to rain or irrigation, the water will fill soil pores. When all the soil pores are filled with water, the soil becomes saturated In saturated soil, the air in the pores is replaced by water If a handful of such saturated soil is squeezed in the hand, some water will run between the fingers Most crops and plant species cannot withstand saturated soil for a long period, because they require both air and water. Generally, most crops and plants cannot withstand saturated soil for more than 2-6 days. After a certain amount of time, excess water from the large soil pores moves downwards. This process is termed as percolation or drainage. The air replaces water from the larger soil pores. In sandy soils, percolation is complete within a period of few hours, while in clayey soils, it may take 2-3 days

After percolation of water from large soil pores, large soil pores have water and air while the smaller pores remain full of water. This stage is the *field capacity* of the soil Such condition is usually considered most suitable for crop or tree growth. Gradually, the water stored in the soil is taken up by the plant roots or evaporated from the topsoil and in such situation the plants gradually die Drier the soil, more tighter is the grip of the soil on marginal water and more difficult it becomes for the plant roots to extract it. The uptake of water becomes so marginal that plants wilt and die. The soil water content, at this stage, is called the *permanent wilting point*

The amount of water actually available to the plant is the difference between the amount of water stored at field capacity and the amount of water stored at the permanent wilting point. The available water content usually depends upon the soil texture and structure. The field capacity, permanent wilting point and available water content are called the *soil moisture characteristics*. They are generally constant for a given soil, but vary widely from one soil to another

Soil classification and survey

Modern classification is based upon the study of the soil profile. Soils are classified into the following well-defined categories:

Higher categories	Order; Sub-Order; Great Soil Group; Sub-Group. These categories give general understanding of soils over large areas indicating their world-wide relationship.
Lower categories	Families; Series; Types and Phases. These categories are more important in recognising local differences and assessing productive capacity of soil for utilitarian purposes (Table 2 3).

Table 2.3 *Classification of soils*

Order		
Zonal	*Inter-zonal*	*Azonal*
Soil develop on well-drained parent material, profile well-developed and in equilibrium with the environment (e g, podzols, laterites)	Soil have a distinct profile Characteristics are more influenced by local relief or parent material than by the normal effects of climate and vegetation (e g, saline and alkali, ground-water laterites)	Without a well developed profile owing to their extreme immaturity (e g, soils on steep rocky slopes or fresh alluvial deposits and on coarse sand found in any climatic region (e g, alluvial and dry sands)

Middleburg (1950) gave a tentative scheme for classification of tropical and sub-tropical soils (Table 2 4).

Important soil groups

(a) *Alluvial.* These soils are derived from water-deposited sediments The difference in properties are due to differences in sediments from which they are derived Drainage conditions produce many variations. They are poorly grained, have greyish colour with motting. They are mostly acidic except in drier areas where they often develop into saline and alkali soils. Calacareous concretions in soil profile are also observed.

(b) *Regosols.* These soils do not have well developed profile but they are derived from material other than alluvium, e.g , volcanic ash, marls and dunes. They are found mostly in coastal areas and deserts.

(c) *Lithosols* These soils are very shallow, consist largely of imperfectly weathered mass of rock They are found especially on steep slopes where little or no true parent material for soil has accumulated.

(d) *Andosols*: These soils are found only on volcanic-ash under humid conditions They are also known as mountain black earths They are medium depth, have a distinct thick black surface layer of medium to coarse-texture and crumb structure, are acidic and

Table 2.4 *Classification of tropical and sub-tropical soils*

Order	*Sub-order*		*Great soil group*
Zonal	Humid region	1a	Podzolic yellow soils with black humic top soils
		1b	Red yellow podzolic soils
		2	Non-laterised red soils
		3	Degraded black clay soils
		4	Alluvial grey and black clay soils
	Arid region	5	Red desert soils
		6	Dark desert soils
Inter-zonal	Calcimorphic	7	Red calcareous soils over lime stone
		8	Black calcareous soils over lime stone
		9	Red calcareous soils over marl
		10	Black calcareous soils over marl
	Halomorphic	11	Saline soils
		12	Ground water lateritic soils
	Hydromorphic	13	Planosols
		14	Organic soils
		15	Lithosols
		16	Regosols (ash, dry sands)
Azonal		17	Alluvial soils

well supplied with nutrients Cinchona, coffee, irrigated rice, palm and tobacco are grown on andosols

(e) *Podzol soils* In tropics, podzols have been observed on acid coarse textured parent material and acid volcanic tuffs under humid tropical climates with rainfall usually greater than 80 inches and without a distinct dry season. They are found on coastal areas as well as at higher altitudes

(f) *Latosols* All these soils are deeply weathered, strongly leached and without any horizon differentiation They are low in organic matter and clay They develop from basic parent material to red, brown to yellow coloured profiles Groundwater laterites are more yellow They are mostly acidic, and resist erosion

(g) *Grumusols* These soils are dark clay soils of warm regions which have been variously named as black cotton soils They develop from variety of basic parent material under alternating wet and dry climates They can be quite deep under riverine areas. They have thick dark brown to black surface horizons, relatively poor in organic matter and have high clay distributed uniformly throughout profile They are sticky and plastic when wet and shrink when dry, producing cracks Calcium carbonate is often present in deeper horizons They are highly base saturated mainly with Ca and Mg cations Neutral to alkaline in reaction

(h) *Non-calcic brown soils and red brown earths* They include non-lateritic brown soils, non-lateritic red loams, *terra rossa,* and possibly the red loams and red earths of India They develop under monsoonic medium dry climates While non-calcic brown soils are developed from acid to neutral parent material, red brown earths develop from parent material fairly high in ferromagnesium minerals and sometimes on basalts and limestones These soils are good for grassland development.

(i) *Grey hydromorphic soils*: These soils are found on transported materials in poorly drained depressions having a fluctuating high groundwater table They show dominant wetness throughout the profile They have thin surface horizon.

(j) *Desert soils*. These soils are developed in arid regions mostly under the influence of physical weathering They are sandy and unleached with severe water and wind erosion. Shifting of partially established sand dunes are common These soils develop on smooth alluvial fans and along broad streams Valleys are often suitable for farming, if irrigation is available

(k) *Organic soils*: These soils originate under humid climates as a result of accumulation of organic matter They have relatively thick organic surface layer, poorly drained and have a high ground water table almost throughout the year. Organic soils represent bog, half bog, peaty, marshy and swampy areas They are found in coastal land swamps and in various depressions in mountain areas.

Soil survey

It is the study and mapping of the soils in the field in their natural environment for fundamental and utilitarian purposes. Fundamental purpose helps to recognise different soils, define their characteristics, and provide material for soil correlation and reclassification.

(a) *Types*. Depending upon the prospective use of soil survey, and details with which the soil boundaries are to be demarcated, the following types of soil survey are recognized

(i) *Detailed surveys*: Elaborate mapping is done, demarcating the lowest categories of taxonomic and mapping units, viz, types and phases, which are generally quite homogeneous. They provide sufficient information for interpretation of various kinds and uses

(ii) *Reconnaissance surveys*. Less elaborate mapping and soil units in which a higher category small scale maps are used These surveys provide broad understanding of the soils and are particularly useful in new and relatively undeveloped regions for general planning

(iii) *Detailed reconnaissance surveys*. Contain elements of both detailed and reconnaissance survey. Areas of better use potentialities are done by detailed survey and areas of lower use potentialities by reconnaissance survey

(b) *Methods* These include study of soil in field and laboratory and traversing and studying soil borings at required intervals Mapping of the soil is done according to well-defined legends Collection of all relevant information about the climate, physiography, hydrology, geology, vegetation, present land use is essential The collection of scientific data about recommended practices and their responses, and socio-economic conditions of the area, is also important

To undertake soil survey of any area, the prerequisite is collection of all available information and record on soil and allied aspects, procurement of base maps and preparing work plans. Useful base maps are aerial photographs and detailed topographical maps. The work begins with a preliminary inspection of the area to understand the broad soil and physiographic patterns and to plan traverses and legends Two important aspects of soil surveys are preparing complete description of mapping units and delineation of soil boundaries.

(c) *Soil mapping units*: Two units are recognized through profile examination maps in general system of classification and mapped in appropriate symbols. In soil survey, it is the lower categories that are studied, defined and mapped.

Soil colloids

In case of soil-water suspension, the water never gets cleared and is far from being transparent, the suspended material remains for indefinite period. This is called *colloidal suspension* The particle size in case of colloidal suspension is 0.003 mm and less. The colloidal part of the soil is one of the most active components of the soil and acts as centre of activity. The soil colloids are derived from both organic and inorganic material. The inorganic colloids are mainly the secondary minerals, for example, clays, hydrous mica and hydrous oxides of Fe and A1. The silicated clay play a very important role in constituting the inorganic colloids as well as of non-colloidal regions, whereas hydrous mica, hydrous oxides of Fe and Al are important in tropical and sub-tropical areas The organic colloids are derived mainly from well-decomposed organic material, called *humus*. The two together form clay-humus complex. This complex serves as the seat of most of the reactions in the soil

(a) Properties of soil colloids

(i) *Adsorption*· The active surface of the colloidal complex adsorbs moisture on its surface in the form of moisture films These moisture films are retained by the colloidal surface with force which reduces with the thickness of moisture film The colloidal complex also adsorbs gases.

(ii) *Electrical charges*. The colloidal complex has negative charge on its surface and attracts positively charged ions such as Ca++, Mg++, K+ The main reasons for the charges are ionization of hydroxyl ion and isomorphous substitutions of cations in these structural units whenever high valency ions are replaced with low valency ions, there is a net residual charge Such events create charge on the surface of the colloidal particle The colloidal particle can be considered as a huge anion by virtue of its carrying negative charge around it Some positive charge may also develop at broken edges of the clay particle and attract negative ions or an ion like PO4–, SO4–, etc

(iii) *Coagulation*. The colloidal particles loose their structural pattern by coming in contact with oppositively charged ions. In highly exposed areas due to heat, decomposition of humus takes place and the humus gets coagulated

(iv) *Tyndal effect* If a soil-water suspension is placed in a path of a beam of light, the particle will appear bigger than their actual size, this is because of diffusion of light by colloidal particles

(v) *Brownian movement* The colloidal particles when seen in the microscope appear in a constant motion This random motion is called *Brownian movement*

(vi) *Dialysis* The property of a semi-permeable membrane to retain colloids and allow crystalloids to pass through it is called *dialysis*. This property is used for purification of colloids.

(b) Humus organic colloids

Various organic materials are systematically decomposed through the agents of bacteria and fungi, etc , and finally reduced to a brownish black amorphous substance, called *humus* It has proteins, polyuronoides, etc They form an appreciable part of organic colloids and in case of sandy soil most of the colloidal content is derived from these materials. The humus contents of the soil depends upon the supply of raw organic material, favourable micro-organisms, favourable temperature and moisture conditions.The humus level in a natural vegetation attains an equilibrium level. This equilibrium humus is stable and contributes to the soil fertility value In certain situations the equilibrium level of humus may change Ordinarily humus is fairly resistant to decomposition but in harsh conditions of high temperature and low moisture, it can degrade and completely disappear from the soil, e g., in arid regions. When a natural forest is cleared, initially humus content increases in the soil because of such factors as rise in temperature, rise in moisture level because of no transpiration loss and faster utilization of the available organic matter supply through bacterial activity This is a temporary change and as soon as fresh organic supply is discontinued because of the lack of return of litter etc., the humus level starts falling. Therefore, it should always be borne in mind to keep the humus at a favourable level so that the soil fertility can be preserved.

(c) Clay inorganic colloids

Soil clay constitutes the inorganic colloids of the soil The soil clay has flake or plate-like structure and mostly consist of silica and alumina plates In many soils in India, hydrous oxides of Fe and Al contribute to the majority of inorganic colloids in the soil The surface of the soil colloids exhibits exchange property due to which the cations are exchanged for other cations due to mass action or adsorptive power. The tenacity with which the cations are absorbed at the exchange side is as under.

$$H+ > Ca2+ > Mg2+ > K+ > Na+$$

The H+ ions are held most tenaciously and Na+ ions least The soil clays exhibit plasticity, cohesion and swelling and shrinkage These properties are the function of soil moisture The moisture contents on which the clays take the given shape and retain it after drying, is called *plasticity* Cohesion is shown by the binding of clay particles together at a certain moisture level, this moisture is called *cohesion moisture* Some clays swell with absorption of water by the soil and shrink when they are dried The swelling and shrinkage gives development of cracks and fissures in the black soil areas

(d) Ion exchange

The ion exchange phenomena is complex and several theories have been put forth to explain it A simplistic view involves ionic activity related to free energy associated with it There are transport controlled and chemically controlled reactions which are probable under different conditions of soil The soil-soil solution interface is the hub of activity for ion exchange More is the colloidal content, greater is the possibility of ion exchange to take place. Nutrient retention is proportional to the enrichment of soil with clay-humus complex. The probable reactions at the soil-soil solution interface are:

1. Transport to interface
2. Transport from interface
3. Absorption
4. Desorption
5. Reaction

The ion can move to the interface and can be removed from the interface in the soil solution through transport mechanism. The ion may remain on the interface due to absorption and return to solution due to desorption due to chemically guided phenomena such as drop in concentration at a point in soil solution or change in the activity of ion in the soil solution There could also be a chemical reaction with soil solids and ions may move in or out.

Soil reaction or pH

The role of pH is among the most difficult of environmental factors to understand but is of central importance. The difficulty lies partly in the complex interaction of other factors (such as the nature and size distribution of particulate phase, the concentration of cations and the precipitation) Soil reaction can be judged by measuring the H+ ion concentration in soil-water suspension. The term pH which is negative log of H+ ion concentration is used to describe the state of reaction of the soil Neutral reaction shows a pH of 7 and values below 7 mean increase in H+ ion concentration and consequent acidity of the soil The pH of a soil, or soil horizon, is usually given as a single value, or range of values, based on standard measurements made with a glass electrode The variation in techniques used produce some small variations in pH value obtained. The merit of this approach to pH determination is that it produces a 'bulk pH' (PH_2) measurement which is an average of all the local pH values and may have a quantitative relationship to them which is useful at least for the purposes of comparing different soils or horizons.

Bulk pH is determined primarily by the balance between hydrogen ions and to some extent Al+++ and basic cations such as Ca++, K+ and Mg++ This balance is modified by other environmental features, such as the nature of the solid matrix of soil and the precipitation. The significance of the solid matrix lies in the proportion of negatively charged particles which it contains Among the mineral fractions, clays have charged surfaces because of unsatisfied valencies in the clay minerals Many organic colloids of the humus fractions are also negatively charged The presence of negative charge at the surface of these materials lead them to attract a "cloud" of cations to the surface region The capacity of soil to attract cations in this way is termed as cation exchange capacity and is usually measured as milli-equivalents of H+ bound per 100 g of soil

In acid soils H+ tends to predominate at the colloid surfaces but in base rich alkaline or neutral situations the main component may be basic cations such as Ca++ These states are by no means permanent The hydrogen ion is absorbed more strongly than other cations so that when an excess of H+ is produced (e g., during the formation of organic or mineral acids such as H_2Co_3 by the decomposition of organic matter) they will exchange with the Ca++ or other basic cations on the surface

$$\text{Ca (absorbed)} + 2H_2CO_3 = 2H + \text{(absorbed)} + \text{Ca} (HCo_3)_2$$

This equilibrium may shift to the left if excess of Ca++ occurs in the soil solution due to release from $CaCo_3$. If the soil is subject to heavy leaching than the removal of the soluble calcium bicarbonate throw the equilibrium strongly to the right and leads to build up of hydrogen ions on the clay surfaces. The H+ held at surfaces determine 'reserve acidity' in contrast to 'active acidity' of the solution, which is in equilibrium with it. Changes in the active hydrogen ion concentration are adjusted by absorption or loss of H+ from the colloidal surfaces.

The excess of H+ associated with clay or humus colloids produces a local pH (i.e , in the immediate region of the surface) which is significantly lower than that of surrounding solution. This difference is likely to remain more or less permanent, except perhaps in extreme alkaline soils where reserve acidity is negligible This then is one of the major sources of difference between pH_{22} and pH

The extreme acidity (low pH) is observed in case of acid peat and high organic matter soils. The extreme alkalinity (high pH) is shown by sodic soils with impaired soil structure and permeability having hard concrete calcium carbonate The humid region soils show acidic pH due to high rainfall coupled with leaching of bases and presence of acids due to decomposition processes in well-vegetated areas The arid region soils show moderately high pH due to high bases such as calcium coupled with moderate to low rainfall and comparatively low chemical and biological activity. At the stage of decay, the formation of acidic products is high and mineralisation is proceeds at such a rate that the buffering effect of bound cations is destroyed. Below the immediate 'decomposer horizons' however the buffering capacity of most soils is such that the leaching of acids from the litter has no noticeable effect on the bulk pH, as is shown by the mineral soils. Nevertheless, it should be re-emphasized that marked local changes in pH occur. Pockets of acid pH may be found in the soil associated with the site of decomposition of roots or stumps Mostly soils are pH neutral. The pH in soils increases with increase in Ca^{2+}, Mg^{2+}, K^+, Na^{2+}, P^{3+} and paucity of Fe^{2+}, Mg^{2+}, Bo^{2+}, Ca^{2+}, Zn^{2+}.

In nature, soil develops a capacity to resist sudden changes in pH on violent treatment of soil with acid or alkali. This is due to the presence of humus, colloids, phosphates, oxalates carbonates and salts etc. This is a natural provision since steady state condition of soil is a result of years of stabilization process and a stage is attained where soil equilibrates with vegetation and atmosphere. Moreover, the soil microbes show high specificity towards pH A slight change in condition can offset the microbial activity and consequent transformations in soil The buffer capacity in soil tries to bring the conditions especially pH back to original value and protect the myriad of dynamic processes going on in it

Mineral nutrients of plants

The plant is composed of carbohydrates, proteins, fats, vitamins, alkaloids, resins, minerals, etc The basic starting material for the synthesis of all these plant constituents are simpler substances like water, minerals and gases. The plant is capable of absorbing almost all mineral elements in nature However, there are some mineral elements which are essentially required by the plants for survival and these nutrient elements are called essential elements

1. The deficiency of these elements make it impossible for the plant to complete its life cycle
2. Such deficiency is specific to the element and it is exhibited in the form of well-defined symptoms and these symptoms can be prevented or corrected by addition of the elements.
3. The element is directly involved in the nutrition of the plant apart from the corrective effects.

There are 16 nutrient elements which have been accepted as essential elements for the plant growth (Table 2.5). Some elements like iodine, cobalt are also considered essential where the vegetation is used for raising animal herds Elements like sodium and vanadium can replace essential elements like potassium and molybdenum to some extent under specific conditions.

Table 2.5 *Essential nutrient elements for the plant growth*

Sl No	*Elements*	*Form in which they are taken by the plants*
1	Carbon (C)	CO_2
2	Hydrogen (H)	H +, HOH
3	Oxygen (O)	O_2, OH, CO_3, SO_4, CO_2
4	Nitrogen (N)	NH +, NO_3
5	Phosphorus (P)	H_2PO_4
6	Potassium (K)	K+
7	Calcium (Ca)	Ca++
8	Magnesium (Mg)	Mg++
9	Sulphur (S)	SO4—
10	Iron (Fe)	Fe++, Fe+++
11	Zinc (Zn)	Zn++
12	Copper (Cu)	Cu++
13	Manganese	Mn++
14	Molybdenm (Mo)	MoO_4
15	Chlorine (Cl)	Cl^-
16	Boron (B)	Bo_3

The first 6 essential elements are known as *major elements* because of the large quantities required for the plant growth Ca, Mg and S are required in moderate quantities and they are called *secondary elements* The rest of the elements from iron to boron are required by plants in extremely small quantities and they are called *micro elements or minor elements*. This differentiation is based on quantities though all the 16 elements are equally essential for good plant growth

Nutrient uptake by plants

The nutrient elements are absorbed by the roots in the form of ions Large amount of nutrients are absorbed through roots compared to the quantities absorbed through leaf surface The ions remain in soil solution and they are absorbed or exchanged at the clay surface (contact exchange) The roots can also absorb nutrients from readily decomposed mineral Depending upon soil moisture and availability of nutrient ions as well as the plant species the absorption may become more important whenever there is deficiency of micro-nutrients especially in horticulture crops There are two processes of nutrient absorption by plants, viz., diffusion and mass flow Diffusion occurs due to transportation pull created at the leaf surface. This pull is transmitted down to roots and water along with nutrients is absorbed. The absorption of nutrients by roots is most efficient in soils having high nutrient concentration, and good aeration

Element like N,P,K, Fe, Cl and S are mobile while Ca, Mg, Zn, Cu, Mn, Mo, etc., are less mobile in the plant (see Plate 4).

Plate 4 *Trainloads of inorganic fertilisers are annually dumped in farm lands Besides creating nutrient imbalances, excesses and injudicious use of chemical fertilisers may turn soil infertile*

Role of essential nutrients

(a) *Carbon, hydrogen and oxygen* Carbon is absorbed in the plant in the form of CO_2 from the air. It is essential for the synthesis of carbohydrates, synthesis of protoplasm, etc Hydrogen and oxygen are derived from the absorbed water through the root system These elements are essential for numerous vital activities of plants

(b) *Nitrogen* The source of nitrogen are soil and atmosphere Nitrogen is absorbed from the soil as nitrates, nitrites and ammonium salts The chief sources are sodium nitrate, potassium nitrate, ammonium nitrate and calcium nitrate Atmospheric nitrogen is fixed and made available to the plant by certain bacteria Nitrogen is absolutely essential for the synthesis of aminoacids, proteins, coenzymes, etc They help in the process of photosynthesis as well

Deficiency symptoms of N deficiency appear first in older leaves As chlorophyll fades, anthophylls and carotenes are unmasked exposing areas of orange and red tints, first in the older leaves and then in the younger ones. Shortage of nitrogen results in the acceleration in the rate of formation of purple pigment anthocyanin in the leaves which become purplish in colour. Stems and twigs also become reddish-yellow, with numerous red and brown spots Because of their small leaves, early defoliation and suppressed shoot growth takes place. Nitrogen-deficient plants are conspicuously thin with sparse-foliage, and are weak The flowering is delayed or is completely suppressed.

(c) *Sulphur*: It is absorbed from the soil as sulphate ion. It is used in the formation of sulphur-bearing amino acids, e.g , cysteine, cystine and methionine. Besides, sulphur is essential for the synthesis of sulphur-bearing vitamins, e.g., biotin, thiamine, and coenzyme A. Sulphur aids in the synthesis of soils and appears to be associated with chlorophyll synthesis. Sulphur is a constituent of ferredoxin and of some lipids found in chloroplasts. Sulphur bridges have an important role in determining protein structure and are often part of the active centres of enzymes

Sulphur starvation results in shortage of protein. As in nitrogen-deficient plant, there is reduced leaf size, stunted growth, general chlorosis, followed by the production of anthocyanin pigments in some species. Sulphur deficiency is more likely on acidic soils.

(d) *Phosphorus* It is absorbed by the plant from the soil in the form of phosphorus ions H_2PO_4 and HPO_4–. Phosphorus is one of the most important elements for the plants. Phosphorus is a vital structural component of the nucleic acids, nucleoproteins, phytins, phospholipids, sugar phosphates, ATP, NADP and numerous phosphorylated compounds. Highest amount of phosphorus is found in maturing seeds and fruits. Phosphorus is actively involved in the synthesis of nucleoproteins. Phosphorus deficiency causes decrease in the rate of protein synthesis. It also results in the accumulation of carbohydrates and soluble nitrogenous compounds. Phosphorus deficiency may cause premature leaf fall and purple anthocyanin pigmentation. The anthocyanin is found in excessive amount The leaves become dark blue-green in colour, and brown necrotic areas develop on leaves and petioles. The growth of root and shoot is extremely restricted. Branching is sparse Flowering is delayed.

(e) *Potassium* It is found in large amount in rapidly growing tissues. It acts as an activator of over 40 enzymes including the enzymes of phosphorylation and protein synthesis According to Webster (1953), potassium is essential for activating the enzymes concerned in the synthesis of polypeptides from amino acids. It is needed by the enzyme DNA polymerase and by the mitochondrion. It is the commonest free ion in the cell, and helps to keep the cell electrically neutral and perhaps stabilises emulsions Potassium is essential for the formation of sugar and starch and also for their translocation throughout the plant. It is also needed in cell division, and reduction of nitrate It is believed to be essential in maintaining the cellular organisation, permeability and hydration.

Potassium deficiency inhibits synthesis of protein, which results in the accumulation of organic nitrogenous compounds in the plant cells Carbohydrate metabolism is checked The rate of respiration increases Scorching of older leaves is the most important symptom on fruit trees The leaves get discoloured The leaf tips and margins show general chlorosis

(f) *Calcium* Calcium has many roles in the structure and metabolism of plants One important function of calcium in the plant is to give strength It is a constituent of the middle lamella, in which it is present in the form of calcium peotate. It is essential for the continuous growth of the apical meristems Maintenance of Na+, K+ and Ca++ within fairly narrow limits would appear to be essential for maintaining the differential permeability of the cell membranes. Calcium affects the hydration of colloids. Calcium helps in the translocation of carbohydrates and amino acids and encourages root development. Calcium reduces the toxicity of such inorganic elements as sodium and magnesium Calcium is believed to be important in the formation of cell memberanes and lipid structures.

Meristematic regions found is stem, leaf and root tips are greatly affected by the absence of calcium, because it is not rapidly translocated to these regions. Ultimately, they die and thus stop the growth of these organs. Chlorosis generally occurs along the margins of younger leaves Calcium deficiency causes malformation of the younger leaves.

(g) *Magnesium* Magnesium is indispensable for the formation of chlorophyll, since it is the one and the only mineral constituent of the chlorophyll molecule. Magnesium is intimately associated with the phosphorus metabolism and is particularly essential for the enzymes involved in the phosphate transfer reaction. It plays an important role in synthesis of ATP from ADP and inorganic phosphate. Magnesium is an activator for many of the enzymes involved in carbohydrate metabolism Magnesium acts as an activator of the enzymes concerned in the synthesis of the nuclecic acids It is also believed to be an important binding agent in ribosomes where protein synthesis takes place.

Deficiency of magnesium invariably results in extensive interveinal chlorosis of the leaves. The older leaves are affected first and younger leaves are affected later Ultimately, leaves develop anthocyanin pigments and necrotic spots.

(h) *Iron* Iron is normally absorbed in the ferrous form, though it can be absorbed in the ferric form as well In a neutral or alkaline soil, iron is in the insoluble form. Iron is always present in the soluble form in an acidic soil and is therefore, readily absorbed by the plants. Iron is essential for the synthesis of chlorophyll Iron is found in ferredoxin, FRS, flavoproteins and the iron-porphyrin proteins which include cytochromes, peroxidases and catalases. It, therefore, plays an important role in respiratory mechanism Iron is primarily concerned in the formation of chloroplast protein in the leaves

Iron deficient plants develop pronounced interveinal chlorosis similar to that caused by magnesium deficiency Whereas, in iron chlorosis, the young leaves may become yellow or white with prominent green veins, the deficiency results in a mottled appearance of the leaf. Sometimes, the chlorotic patches in a leaf are due to presence of iron in the unavailable form in such spots only Its deficiency seriously impairs aerobic respiration Fruit trees are particularly sensitive

(i) *Manganese.* Primarily manganese functions as an enzyme activator in several reactions of respiration and nitrogen metabolism The enzymes malic dehydrogenase and oxalosuccinic decarboxylase in respiration and nitrate reductase and hydroxylamine reductase in nitrogen metabolism require manganese as activator Manganese also plays some role in the synthesis of chlorophyll and in the transfer of electron from H_2O to photo-oxidised chlorophyll in photosyntesis

Manganese deficiency also causes chlorosis which is distinct from mangnesium or iron deficiency The leaf takes a mottled appearance The chloroplasts lose chlorophyll and starch grains and become yellow-green in colour. They become vacuolate and granular and finally disintegrate

(j) *Boron.* It is absorbed as an anion, i e, borate or tetraborate, rather than as a cation like the other metallic nutrients. Its main function is in the translocation of sugar It has been seen that places of high metabolic activity in plant require high quantities of sugar and are the first to be affected in the absence of boron. Boron is also believed to affect flowering and fruiting, cell division, metabolism, active salt absorption, photosynthesis, etc.

Boron deficiency results in the death of shoot tip. The root tips die and the shoot growth is stunted Flowers are not formed The leaves have a coppery texture Internally, carbohydrates and aminoacids accumulate. Boron deficiency tends to shift metabolism from glycolysis to pentose phosphate pathway Physiological diseases like internal cork of apples, browning of cauliflower and heart rot of sugarbeet develop as a result of boron deficiency.

(k) *Copper*· The element is required in very small quantity It is very toxic, when present in larger quantity It acts as a catalyst in oxidation reduction reactions, as it is a constituent of certain oxidising and reducing enzymes It is a part of plastocyanin and thus may function in electron transport chain of photosynthesis.

Copper deficiency causes some physiological diseases, e g, die-back disease of citrus and 'reclamation' disease of cereals and leguminous plants.

(l) *Zinc* Zinc functions as activator of certain enzymes, e.g, carbonic anhydrase, alcohol dehydrogenase, hexose kinase, etc. Zinc is essential for the biosynthesis of the plant auxin, indole-3-aceticacid The element is also believed to be concerned with protein metabolism

Zinc deficiency causes reduced stem growth due to decreased synthesis of auxin It results in stunted vegetative growth and distorted leaves Chlorosis in the interveinal regions of the leaves is another effect of the element's deficiency The internodes are reduced in size and the effect is sometimes referred to as 'little leaf' disease Other deficiency diseases white but of maize, 'mottle leaf' disease of apples and walnut The absence of zinc also suppresses seed formation and causes malformations in fruiting trees

(m) *Molybdenum* Molybdenum is required in very little quantity by the plants The main role of molybdenum in plants has been found to be in the nitrogen metabolism It acts as an activator for the enzyme nitrate reductase

Its deficiency results first in the chlorotic interveinal mottling of the lower leaves It also inhibits the flower formation. 'Whiptail' disease of cauliflower has been reported to be due to deficiency of the element

(n) *Chlorine* Recently chlorine ion (cl^-) has been shown to be essential in a number of plant species in small but definite amounts for their healthy growth Chloride ions are essential in the transfer of electron from H_2O to photo-oxidised chlorophyll in photosynthesis

Role of other elements

Several other elements, over and above the 16 essential elements, are present in plants in large or small amounts It is supposed that most of these non-essential elements are quite important for the normal growth and development of the plants Among them the most common are sodium, silicon, iodine, fluorine, cobalt, selenium, aluminium, etc

Sodium is essential for blue-green algae and at least for some of the higher plants. It regulates the transportation of amino acids to the nucleus, and, therefore, controls the synthesis of nucleoprotein It is believed to be involved in stomatal opening, oxalic acid accumulation, nitrate reductase activity, and in maintenance of water balance.

Silica is essential for cell walls of diatoms but its function in other plants is not known. It also occurs in cell walls of some grasses

Cobalt is part of Vitamin B_{12} which itself is a part of an enzyme. It is known to be essential in symbiotic organisms for nitrogen fixation. It is needed by the enzyme ribonucleotide reductase in rhizobium.

Soil organic matter

The sources of organic matter in the soil include living or dead form of animals, plants and other forms of life The organic matter represents certain stages in an endless turnover of carbon, hydrogen, oxygen, nitrogen, phosphorus and sulphur between living organism and the mineral matter Grasses, trees and tree remains, bacteria, fungi, soil animals contribute towards the level of organic matter in the soil to a large extent When fresh organic matter decomposes, due to the action of various types of micro-organisms, humus is produced which resists further decomposition and forms a complex with the soil clay

Functions of organic matter

(1) Coarse organic matter on the surface reduces the impact of the falling rain drops. Surface runoff and erosion are thus reduced
(2) The addition of easily decomposable organic residues cause synthesis of complex organic substances that bind the soil particles into structural units called aggregates
(3) Live roots decay and provide channels where new plant roots grow more luxuriently.
(4) Organic matter increases the water holding capacity of the soils The permanent wilting percentage is increased. Organic matter definitely increases the amount of available water in sandy and loamy soils
(5) Serves as reservoir of chemical elements that are essential for plant growth Most of the soil nitrogen, phosphorus and sulphur exist in organic forms
(6) Organic matter upon decomposition produces organic acids and carbon dioxide, which helps to dissolve minerals such as potassium
(7) Organic matter helps to buffer soils against rapid changes in pH due to the addition of lime and fertilisers
(8) Humus provides a storehouse for the exchangeable and available cations e g potassium, calcium and magnesium
(9) The organic matter serves as a source of energy for the growth of soil micro-organisms
(10) Fresh organic matter supplies food for such soil worms as earthworms
(11) Evaporation losses of water are reduced by organic mulches
(12) Trashy, coarse organic matter on the surface of soil reduces losses of soil by wind erosion
(13) Surface mulches lower soil temperatures in the sun and keep the soil warmer in winter
(14) Fresh organic matter makes soil phosphorus more readily available in acid soil

(15) Organic acids released from decomposing organic matter help to reduce alkali in soils.

Carbon and nitrogen ratio of organic matter

The ratio of carbon and nitrogen contents in the fresh organic matter is one of the important criteria which regulates the state of decomposition of the organic matter and the availability of mineralised nitrogen to plants. A wide C:N ratio (40:1) is observed in freshly added organic matter in the soil Upon decomposition carbon is lost through the formation of CO_2 from the soil and the ratio narrows down to about 15:1 or 10.1 The mineralised nitrogen becomes available for plant absorption at this ratio There is some time lag to arrive at a narrower C:N ratio

The mixed population of microbes attack the freshly added organic matter and large quantity of carbon dioxide is released mainly due to their respiratory activity The nitrogen is utilized for the synthesis of body proteins by the mircobes and thus it is rendered immobilized. The loss of carbon leads to decrease of the C·N ratio to a value where available nitrogen exceeds the demand of the mircobes and plants can also utilize it. Narrowing down of C:N ratio also indicates that decomposition of the organic matter is reaching a state of stability.

Composition

To find the exact composition of the organic matter has been an extremely difficult task, since humus forms complex with the mineral matter of soil Organic matter yields following chemical constituents

Carbohydrates (sugar, starches and cellulose)
Lignins
Fats, oils and waxes
Resins
Proteins
Pigments
Minerals, e g , Ca, P, S, Fe, Mg and K

Soil nitrogen

Content

This is abundant in supply and ranks only after hydrogen, However, ploughed layer of soil contains extremely small quantities (0 02% to 0.4%) The elemental nitrogen has to be biologically fixed before it is useful to the plants The content in soil depends largely upon the efficiency of this fixation amongst many other factors influencing the content in soil The growing need of food, fibre and forestry products necessitates continued supply of sufficient quantity of nitrogen to the plants. Industrial processes have been developed now to chemically fix this elemental nitrogen in the form of fertilisers Thus, concentrated nitrogenous fertilisers have proved to be vital in meeting the needs of the present and possible future The proportion of nitrogen found in the soil has fairly important relation with temperature. The percent nitrogen decreases with increase in the mean annual temperature of the region The nitrogen content also varies with topographical situation, e.g , in a depression the nitrogen content is high due to high amount of soil-water supporting luxurious vegetation growth. Finer the texture of soil, more is the nitrogen content e.g., sandy soils show 0 2% N, whereas silt loam soils show 2.3% N (more than 10 times).

Distribution in soil

Nitrogen is not uniformly distributed in the soil. The distribution of isotopic nitrogen under well drained and submerged condition involves complicated processes in which physical, chemical and biological forces play important role

Forms of nitrogen

There are various forms of nitrogen found in the soil due to its varied valency states. These forms are: nitrous oxide (N_2O), nitric oxide (NO), nitrogen dioxide (NO_2), ammonia (NH_3), ammonia (NH_4), nitrite (NO_2) and nitrate (NO_3). Except ammonium nitrite and nitrate all other forms are gases. Large quantities of soil nitrogen occur in organic combination as proteins. The group of bacteria which convert nitrogen from ammonium to nitrite form are nitrosomonas and the further conversion to nitrate is brought about by nitrobacter. The various processes are termed as follows:

(a) *Ammonification*: Conversion of nitrogen from organic form to ammonium form is brought about by ammonifiers and process is known as *ammonification.*

(b) *Nitrification* This process covers the conversion brought about by nitrifiers from NH_4 to nitrite forms of nitrogen.

(c) *Nitrogen mineralisation* When nitrogen, which was originally found in organic combination is transformed through the agency of micro-organisms to mineral form such as nitrate, the process is known as *nitrogen mineralisation.*

(d) *Nitrogen immobilisation*: When there is a temporary arrest in mineral nitrogen supply to plants or it is consumed instantaneously, the process is termed as *nitrogen immobilisation.* The nitrogen requirement of fast increasing microbial population exceeds the supply available in the soil. The microbes then, offer a keen competition to the plants and for some time consume all the available mineral nitrogen to meet their requirements. The nitrogen is thus immobilised

(e) *Denitrification.* The process leading to the loss of nitrogen in gaseous form due to the action of denitrifying bacteria working under submerged soil conditions

Nitrogen level in soil

The existence of nitrogen in the soil is governed by a host of different agro-climatic, soil and management factors The quantity of available nitrogen in any soil at any time will depend upon the integrated influence of these factors. Various measures maintain high levels of nitrogen in soil which include the efforts to fertilise soil with manures and fertilisers along with proper supply of water Good soil management and checking the leaching losses (nitrate is very mobile in soil) will add to the level of nitrogen by conserving nitrogen losses

Micro-organisms of the soil

Raw organic matter in the soil is not directly used by the plants as food It must be broken down first into humus and then into simpler products before it can be so utilized. This work is done by different micro-organisms, which are found in billions in the soil The decomposition of organic matter primarily forms part of the feeding and growth processes of these microscopic plants and animals. Sugars, starches and proteins are broken down first, then cellulose and fatty substances (lipids); and lastly, lignin. When organic matter becomes chemically and biologically inert, the soil becomes infertile, despite its presence. However, not all the soil organisms are beneficial. There are certain bacteria which under anaerobic conditions of water-logged soils cause denitrification, releasing free nitrogen which gets lost into the air Some others cause plant diseases Some intermediate products of bacterial decomposition of soil-organic matter or certain organic products synthesized in the soil by some micro-organisms have important growth-promoting or plant-protecting (i.e , antibiotic) properties.

Kinds of soil organisms

The soil micro organisms have been classified as follows

Microflora: (i) Bacterial, (ii) actinomycetes, (iii) fungi, and (iv) algae

Macrofauna (i) protozoa, and (ii) nematodes

Besides microfauna, the soil harbours a large number of worms and insects of different kinds and sizes

Density of population

The soil organisms vary in number from a few per hectare to many millions per gram of soil. The density of population is determined by food supply, moisture, temperature, physical condition and the reaction of the soil In more or less neutral soils, bacteria dominate over other types of microscopic life. If the soil is acidic and rich in organic matter, fungi predominate. Algae abound on or near the surface of the soil in constantly moist and shady situations. Under favourable conditions, such as that obtained after the ploughing in of a green-manure crop, the bacteria multiply enormously On the other hand, in sandy desert soils or under water-logged conditions, they are very scarce As among the soil microflora, it is estimated that generally bacteria form about 90% of the total population, actinomycetes about 9%, and the fungi and algae together about 1% Among the soil fauna, protozoa are the most abundant, followed by nematodes, worms and insects

Bacterial activity

The soil microflora typically produce ammonia from organic compounds when they set free more of nitrogen from the organic matter on which they are living. Ammonia, is converted into nitrites by one group of organisms called *nitrosomonas* and nitrites are further converted into nitrates by another group of organisms called *nitrobacter* The process of conversion of ammonia into nitrate is called *nitrification.* The nitrate-forming bacteria are generally confined to the top 25 to 30 cm of the soil These organisms are most active between 25 degree to 30 degree centigrade and under favourable conditions of tillage, aeration, neutral soil reaction and moisture content at field capacity The bacteria reduce their activity when the pH value of the soil falls below 5 They, however, become active again when the pH is raised to about 6 by liming The large supplies of carbon in the raw organic matter favour an enormous multiplication of bacteria which use the nitrates released by the nitrifying bacteria. A similar effect may also be produced sometimes by heavy green manuring The symbiotic bacteria penetrate the rootlets and induce the leguminous plants to produce nodules at the points of entry The bacteria grow and multiply inside the nodules, getting their carbohydrate and mineral food from the plant and nitrogen from the air to form nitrogenous organic compounds, e g , proteins, which then become available to the host plant. The amount of nitrogen added to the soil varies from 50-150 kg per ha In the absence of the nitrogen-fixing bacteria, no nodules will be formed by the leguminous plants and no atmospheric nitrogen will be fixed

Other organisms

Azatobacter and other non-symbiotic nitrogen-fixing bacteria work independently of any host crop Under optimum laboratory conditions, azatobacter has been found to fix a considerable amount of nitrogen

(a) *Actinomycetes*: They are similar in size to bacteria but resemble moulds in their growth and physiology They can grow in the deeper layers of the soil and under drier conditions, and need less nitrogen They also synthesise chemical substances

(b) *Fungi*. These organisms produce microscopic threads called mycelia, which may be found in the disintegrating organic matter on the surface of the soil or on plant roots in the upper strata below the surface Many of the fungi live on dead organic matter, others are parasites which attack live plants and produce highly destructive epidemic diseases. Still others are parasites that can also live in the absence of host plants

(c) *Algae* They are microscopic or larger plants containing chlorophyll. They are found in large numbers in the top layer of constantly moist soils Some of them have been shown to be capable of fixing atmospheric nitrogen

(d) *Protozoa* Soil protozoa are unicellular animals, feeding either on soil organic matter or on bacteria, regulating the number of the bacteria in the soil The larger forms are found in very wet conditions or in swamps

(e) *Worms and insects* Most of the soils are inhabited by worms, insects and other animals of different sizes They feed on plant remains, which are ingested along with large quantities of earth Their excrements are deposited on the surface Insects and some other larger animals promote aeration and water percolation They make channels and burrows in the soil primarily for their protection or in search of food

Fertilisers and manures

Human interference in the ecological set up tends to reduce the efficiency of the recycling of nutrients. There is irreversible depletion of soil fertility making the soil poorer with time The advantage of applying fertilisers to the soil is that the nutrient depletion could be checked effectively and the returns could be maintained

(a) Nitrogenous fertilisers

The nitrogen containing fertilisers in India supply the nutrient in ammonium and nitrate forms in combination with other nutrients like calcium and sulphur These fertilisers are shown with their nitrogen content as below

Name	*%N*
Ammonium sulphate	20.6
Ammonium sulphate nitrate	26.0
Calcium ammonium nitrate	20.5
Urea	45.0
Ammonium chloride	25.0

(i) *Ammonium sulphate*: Application of this fertiliser leaves some residual acidity in the soil, which needs sufficient calcium reserve in the soil or else liming is done to maintain a favourable soil reaction. The need for liming arises only after a prolonged use of the fertiliser.

(ii) *Calcium ammonium nitrate*: Ammonium nitrate is a source of nitrogen, containing 33% of the nutrient. This compound suffers from two major defects, viz., its hygroscopic and explosive nature Calcium ammonium nitrate (CAN) contains 20.5%N Besides, it has 35% $CaCO_3$ and 5% $MgCo_3$, the Ca and Mg improve the physical conditions of the soil.

(iii) *Urea*. This compound is one of the most widely used fertiliser in the world. It is immediately soluble in water. It is slightly acidic in reaction and is economical to apply The nitrogen in urea is present in amide form.

(b) Phosphatic fertilisers

The phosphorus supplying fertilisers rank equally with nitrogen in importance. The phosphorus levels show similar fluctuations due to different set of conditions The nature of valency state occurring in the fertiliser material determines the solubility of phosphorus in soil. The fertilisers have been classified according to the solubility as below:

(i) *Water soluble phosphatic fertilisers*.
- — Super phosphate (ordinary grade) 16 to 20% P_2O_5
- — Concentrated super phosphate 40 to 48% P_2O_5
- — Monoammonium phosphate 11% N + 48% P_2O_5
- — Diammonium phosphate 21% N + 54% P_2O_5

(ii) *Citrate soluble phosphatic fertilisers*:
- — Dicalcic phosphate 35-40% P_2O_5
- — Bauc slag(Indian) 3-5% P_2O_5

(iii) *Insoluble phosphatic fertilisers*.
- — Rock phosphate 20-30% total P_2O_5
- — Bone meal 3% N + 18-20% total P_2O_5

In case where phosphorus demand of the plant is immediate, water soluble form of phosphorus can be applied For horticultural crops, citrate soluble phosphorus can be applied and for trees growing over a fairly long period, citrate soluble or even finely ground bone meal and rock phosphate can be applied

(c) Potash fertilisers

Potash fertilisers have not become common in India because of the fact that most of the Indian soils have sufficient potassium levels. However, with increasing pressure on land for raising food, fibre and timber production, potassium is depleting from the soil to a level where application of potash fertilisers become necessary. Chloride and sulphate of potassium are two important chemical forms through which potassium is applied to the soil Potassium chloride or nitrate of potash has 60% of K as K_2O and potassium sulphate contains 50% of K as K_2O.

(d) Organic manure

The litter from trees, twigs, animal excreta or the rubbish constitute the organic source of plant nutrients known as manures. On complete decomposition, the manure is able to release nutrient in available form in addition to its influence on the physical conditions of the soil.

During decomposition, there is a considerable loss of nutrients through volatilisation and leaching. If the manure is allowed to decompose in trenches in a covered state, the decomposition will be proper. The chemical composition of the manure depends upon the nature of the plant material Generally, this type of manure will show a content of 0 8% nitrogen, 0.3% P_2O_5 and 1% K_2O. Compost is also another variety of manure The source of the organic matter to make compost is different The raw material for compost include farm, village and urban refuse, straw fibre waste, sugarcane waste, rice hulls and other residues Composting is also done in trenches with some special care to check growth of flies, mosquitoes and other menacing insects There is a practice to add superphosphate to reduce loss of nitrogen and ammonia, to increase the phosphorus content in manure and to improve the nutrient balance and utilization of phosphorus. To check odour and insects, hydrated lime and borax are added

Organic matter in soil can be raised by growing good leafy crop like sunnhemp, *moong*, etc., for about 60-70 days and then ploughing it back to the soil The practice is called *green manuring* There should be sufficient moisture in the soil to allow proper decomposition or else there can be an increase in the mite population feeding on partially decomposed plant remains There are other sources of organic manure like saw dust which can be added to the soil. Saw dust is poor in nutrients, e g , a ton of saw dust gives 2 lbs P_2O_5, 4 lbs of N, and 4 lbs of K_2O. Saw dust absorbs good deal of water It improves the physical conditions of soil. The urban waste like sewage has also been put to considerable beneficial use by applying to soil This waste is rich in nutrients like nitrogen and phosphorus. Sludge is also allowed to digest naturally and applied to the soil Naturally digested sludge is poorer in nutrient content than the activated or aerated sludge The sludge is poorer in potassium.

Evaluation of soil fertility

An educated fertiliser application will be much more useful to the plants than merely addition of any fertiliser in approximate quantities To know the soil nutrient requirement, it is essential to evaluate the soil fertility before hand There are different ways which suit typical working conditions and the plant types for evaluation of soil fertility.

Chemical methods

(a) *Soil analysis* The total analysis gives over estimated results Weaker acids are used for better results. Alternatively, tests for available nutrients have been evolved using chemicals as nutrient extracts from the soil. This approach has been found to correlate well with plant growth response

(b) *Plant analysis*. Plants can be used to show requirement of minerals by a preliminary exercise. Total analysis of plant tissues in acid extract could give values which could be pooled for large number of samples to work out limits for sufficiency. For immediate appraisal of plant nutrient concentration, rapid tissue tests for nitrogen, phosphorus and potassium can be run using suitable chemicals. The metal-ions and micro-nutrients in particular are known to activate enzymes With good laboratory facilities the enzyme activity can be studied using soil as medium of growth and can be correlated with the ion concentration.

Biological methods

(a) *Use of higher plants*: Use of plant growth response to application of varying doses and types of fertiliser nutrient combinations has been used most profitably. These are known as *fertiliser trials* To study the effect of one factor, simple trials are conducted and to know interaction of nutrients multiple trials are conducted

There is a limit to which increase in yield will occur with increase in nutrient application depending upon the efficiency of utilisation Neubaur's exhaustion technique uses plant exhaustion of nutrients from a volume of soil Indicator plants have also been used to indicate nutrient content available in the soil. Visual diagnosis is employed in cases where deficiency at a later stage cannot be discovered Foliar spray is tried to ascertain the deficiency element and concentration suitable to relieve the plant deficiency

(b) *Microbiological methods* Use of micro-organisms to work out the soil nutrient availability has also been done Laboratory facilities are essential for such work Azatobacter plaque test is sensitive to acidity and phosphorus The weight of tissues of these micro-organism indicates the nutrient content in soil. These tests are particularly useful to test for micro-nutrients Evolution of carbon dioxide has also been related to the growth of micro-organisms and consequently to nutrient available in the soil

Types of soils in India

(a) *Red loamy soils*. The red loamy soils in particular are formed by the weathering of the rocks like gneisses, diorites relatively richer in the clay-forming minerals and correspondingly poor in silica. In some red soils, lime concretions in the form of nodules or thick veins are found to occur the texture of these soils may vary from loam to silty clay and clay. The normal red loamy soils have a pH around neutrality or slightly on the acid side, while the soils containing lime may show a pH 8 5 The A-horizon which may have a depth ranging from 25 to 40 cm may have a reddish brown loam with a crumb structure and the B-horizon going down to 70 to 80 cm from the surface may have a dark brown loam or clay

(b) *Red sandy soils* These soils are generally from granites, coarse grained granites, quartzites, sandstones, etc They are characterised by being rich in the fine and coarse sand fractions The clay minerals become coated with red hematite or yellow limonite or a mixture of two oxides of iron forming a red, yellow or reddish yellow soil The yellowish soil becomes red when the limonite undergoes dehydration and changes to hematite The characteristic clay mineral present in these soils is of the kaolinitic clay. The majority of these soils are slightly on the acidic side with a pH ranging from 4.5 to 6 5 while a few may have a pH on the alkaline side. The red sandy soils have a moderately deep A-horizon of pale reddish brown. The B-horizon is dark reddish brown loam or sandy clay loam of varying depths The depth may vary from 15 cm to 30 cm. The C-horizon is a weathered parent material of disintegrating coarse grained granite This material may retain the morphology of the rock structure to a considerable extent. The texture may vary from gritty coarse sandy clay to gravely loam

(c) *Laterite soils* Laterite is generally reddish or yellowish-red in colour and often has a vermicular structure. The formation may be massive and firm or may be in the form of loose aggregates of a nodular ferruginous mass. The soil derives its name from the Latin term 'later' meaning brick. Latertic soils are those associated with and are derived from laterites The decomposition of only part of the colloidal complex is presumed to have taken place and there is a large proportion of the primary kaolinitic minerals than in laterites. As the laterites do not contain primary clay minerals, they may show the typical properties of clay such as plasticity cohesion, shrinkage, expansion, and base exchange properties. The soils are in some cases deep but in many areas rather shallow.

(d) *Red and yellow soils* In the east-central and north-east-central parts of India occur soils which are characteristically yellow in colour. The range of colour may be from reddish-yellow to yellowish-brown and the soils are usually fine textured They are derived from a variety of rocks underlying in the profile at depth varying from 1 to 2 m Micaceous quartzite shists, phyllites, horneblende schists and gneisses, are some of the rocks giving rise to these yellow soils. In some cases poor drainage conditions may be the cause of the yellow colour. The soils have a pH around neutrality or else slightly on the acid side The A-horizon of these soils is loam to silty loam in texture and are moderately rich in humus. These soils possess a textural B-horizon with colour of high chroma which are usually yellow, but at times red Pigmentation due to soft nodular iron may be found in this horizon.

(e) *Black soils*. Soils with a chracteristically dark colour ranging from dark brown to deep black, occur extensively in the central and south-central part of India These have been classified for purposes of mapping in a broad manner into different groups based upon the depth of their formation Soils possessing depth ranging from 30 to 50 cm are described as shallow black soils, those having depth ranges from 50 to 120 cm as medium black soils, and those with depth in excess of 120 cm and going down to 200 cm and over as deep black soils As a group these soils are fine-textured and their clay content varies from 40% to 60% They are plastic and sticky when wet and very hard when dry These soils are popularly described as 'self-mulching' or 'self-ploughing' soils

(f) *Mixed red and black soils* The occurrence of red and black coloured soils side by side in areas of varying sizes and unpredictable patterns is a fairly common feature in transitional areas where either of these soils are found In view of the difficulty of separating the location of the individual soils in the soil map, these soils have been grouped as a category of the mixed soils In many cases in area of predominantly red soils, while the red soils occur in terrain of elevated topographic features, the black soils may be found in the lower topographic levels The higher moisture regime and the accumulation of organic matter in the lower levels tend to form darker coloured soils of finer texture The greater mobility of the montmorillonitic clay may also be a factor in assisting the accumulation of these black soils in the lower levels. In areas of predominately black soils, occurrence of patches of red soil are not of unusual occurrence. In such cases, field observations indicate that the black soils overlay the red soils. The black soils being composed of fine clay are naturally more impervious to drainage and consequently more erosive and are invariably spread over the adjoining red soils of varying shades, which are best described as a mixture of red and black soils.

(g) *Alluvial soils*: These soils are a very large group of soils formed by transportation due to streams and rivers and deposition over the flood plains or along the coastal belt The character of the soils vary a great deal and reflect the nature of soils that occur in the region. Their colour, texture and quality accordingly vary and also their development in regard to profile differentiation. Most of the young alluvium show little or no horizon differentiation, while the older alluvium show distinct yellow to deep black soils and their texture can vary from coarse sand to fine clay

(h) *Deltaic alluvium*· The soils of the deltaic alluvium represent the heterogeneous types of sediments brought by rivers and deposited at the mouth. The east coast of peninsular India is characterised by the formation of deltas at the mouth of the major rivers of the subcontinent that flow into the sea Of these rivers the Ganges and the Brahmaputra flow from the Himalayas and drain the extensive plains of northern India; the Mahanadi, the Godavari and Krishna, the Deccan plateau and the Central Indian plains, while the cauvery drains the southern part of the peninsula.These rivers carrying the alluvium of the extensive areas they traverse, deposit them at the regions where they join the sea, and these deposits form the alluvial soils of these deltas.In the great flood plains, the material is mainly clayey, sometimes loamy and sandy. The Gangetic plains have light coloured silty and silty clay soils. The Mahanadi delta alluvium are light brown and light yellow in colour and in texture, silty loams, loams and sandy loams These reflect, to a large measure, the colour and texture of the soils of the east central plateau of Madhya Pradesh and Orissa states Godavri and Krishna rivers, draining the black soils derived from the basalt traps, are largely composed of dark coloured fine textured silty clays and clays The alluvium of Cauvery delta, while not truly representing the red sandy and coarse textured soils of the granitic area, through which most of the river's course lies, contain a high proportion of dark coloured silty and silty clay soils. The accumulation of organic matter in the A-horizon vary a great deal and reflect the drainage and cultivation conditions of the respective areas. Thus, the Gangetic alluvium at the mouth of the Ganges which is largely swampy, shows considerable accumulation of organic matter, the natural vegetation being mangrove etc

(i) *Alluvial soils*· These soils represent the vast tracts of riverine alluvium of the Indo-Gangetic plain. The deposits of the great rivers: the Jamuna, the Ganges, and their tributaries—the Gandak, Gomti, Ghagra and others, which flow out of the Himalayan ranges, have accumulated over long periods in the northern part of the sub-continent The area stretches for a length of nearly 1000 miles in an east to west direction and a width of about 200 miles, and is characterised by a topography which is monotonously level and with a general gradient of about 1% from the north-west to the south-east The depth of the alluvium is great and may extend to many scores of feet. These water deposited sediments are in a large measure old, though newer deposits are continuously being made, particularly in the areas adjacent to the river courses. The colour of the soils range from pale grey through yellow and yellow brown to dark grey. The texture is generally silty, though loams and silty clay loam soils are not infrequently met with A well-formed B-horizon possessing strong angular blocky structure is met with. These soils, if not badly affected by salts or suffering from drainage impedance, are fertile and respond well to manuring.

(j) *Desert soils*: The soils are found characteristically in the arid zone in the north western region in the states of Rajasthan and Punjab and lying between the Indus river on the west the Aravalli range of hills on the east, are described as desert soils They are regosols on wind blown sand and sand dunes. They are coarse textured and are derived from the disintegration of rocks in the adjacent areas and blown in from the coastal region and the Indus valley These soils are composed of sand to a depth extending beyond 50 cm The A-horizon is weakly developed or absent as on shifting sand dunes. The soils show no or only a weak B-horizon. Regosols on young dunes are usually yellowish-brown to very pale brown in colour. Some of these soils contain a high percentage of soluble salts in the lower horizons. They possess fairly high pH and varying amounts of $CaCO_3$ They are low in organic matter.

(k) *Brown hill soils*: These soils occur often in hilly regions and under moderately heavy vegetation. The soils are formed over a variety of parent rocks, but in the sub-Himalayan region where they are characteristically located, this material is sandstones, grey micaceous sandstones, and shales The original vegetation was mainly coniferous, and the soils have developed to their present condition after the removal of the original vegetation They form a system of low foot-hills corresponding to the Shivalik ranges The rainfall in the region of their occurrence is moderately high and in the range of 40-70 inches every year The surface soils are dark brown in colour and loam to silty clay loam in texture and moderately rich in organic matter The B-horizon is fairly deep and of 50 to 80 cm depth, with texture in the silty loam to clay range, and compact. These horizons are lacking in free lime. Below this layer are the weathered parent material from sandstones and shales.

(l) *Mountain meadow soils*: High up in the Himalayan region at elevations where trees do not grow, and also on the slopes with a southern aspect at lower elevations, exist soils of moderately shallow depths developed from the sandstones and shales The soils, because of their relatively thin formation and the poor profile development, may also be considered as *skeletal soils of the Himalayas*. The vegetation is mainly grass and the growth of the grass helps to afford the binding material to prevent the loss of soils through wind and snow action The built up of organic matter from the grassroots is assisted by the relatively low temperatures prevailing in the region The soils in the nature of their formation vary a great deal in their texture and structure, being mixed with varying proportion of the partly weathered gravel and rock pieces of the sandstone and shaky material

3

Soil Erosion

Erosion may be defined as the detachment and transportation of soil Mainly water is responsible for this erosion In many locations, wind, glaciers, etc, are also the agents causing soil erosion The natural erosion under a balanced condition of forest and vegetative cover is responsible for creation of earth's crust over millions of years Weathered and disintegrated rocks mixed with decomposed organic matter got deposited on the surface during this slow process of soil formation This topsoil is the basis of preservation and growth of life on earth. Over a period of years, biotic pressures started Encroachments for cultivation, tree felling for firewood, small timber, thefts and fires, uncontrolled grazing, constructional activities, etc, created situations for heavy soil erosion.

Out of the total geographical area of 329 m ha an area of about 150 million hectares is subjected to water or wind erosion Compared to this, a net area of about 140 million hectares is cropped at present It is estimated that 53.3% of total geographical area of the country is subject to various erosion and land degradation problems like saline alkali soil, waterlogged areas, ravinous and gullied lands, area under shifting cultivation, desertification, etc. Out of a total geographical area of 329 m ha about 127 m ha are affected by serious problems of soil erosion. Soil erosion leads to far-ranging impacts like formation of gullies and floods causing damages to farm lands and villages, drop in flow during the dry season, consequent loss of crops, siltation of reservoirs and canals The continuous land degradation by soil erosion is degrading the production base and destroying balance between land-water-plant-human-animal systems This has resulted into economic insecurity and ecological imbalance

It has been estimated that sheet and rill erosion takes place at the rate of 4-10 tons/ha/year in red soil, 17-43/ha/year in black soil and 4-14 tons/ha/year in alluvial soils Gully erosion has resulted in 33 tons/ha/year soil loss in ravine areas Hill side erosion in landslide area results in 80 tons/ha/year soil loss Erosion occurs in agricultural lands, construction sites, roadways, disturbed lands, surface mines and in areas where natural or geologic disturbances take place The deposition of eroded sediments take place at the base of concave slopes, strips of vegetation, flood plains and reservoirs Sediments deposit due to reduction in the flow velocity.

In recent analysis of annual soil erosion rates in India (Dhruva Nayarain and Ram Babu, 1983), it was estimated that about 5334 million tons (16.35 tons/ha) of soil is detached annually due to agriculture and associated activities Streams, rivulets and rivers carry about 2052 million tons, of which 1572 million tons (29% of the total eroded soil) are carried away by various rivers into the sea every year and 480 million tons (10% of the total eroded soil) are being deposited in various reservoirs

Basic processes

Erosion and sedimentation embody the process of detachment, transportation and deposition of soil particles (ASCE, 1975) Detachment is the dislodging of soil particles from the soil mass by the erosive agents Transportation is the movement of detached soil particles from their original location. Sediment travels from upland sources through the stream system and may eventually reach the ocean (Holeman, 1968) Not all sediments reach the ocean, some of these sediments are deposited at the base of the slopes, the reservoirs and on floor plains (ASCE, 1975). Detachment and transport are basic processes occurring on source areas while transport and deposition are basic processes occurring in sink areas. Soil particles are detached either by raindrops impact or flowing water Rate of detachment is non-uniform in time and space owing to variation in rainfall, runoff, soil, slope and cover conditions Detached particles are transported by raindrops splash and runoff An impacting raindrop lifts detached particles from the soil surface and launches them in all directions Although some net down-slope transport occurs depending on the slope steepness, the amount is small compared to transport by runoff

Runoff transports particles as bed-load and suspended-load depending on flow hydraulics and sediment characteristics Thin overland flow can transport only very small particles, whereas raindrop impact lifts large particles in the flow, so that flow can move them short distances down slope before settling down on the soil surface When the sediment load exceeds the capacity to transport coarser-sized particles present in the sediment-load, the sediment gets deposited Reduced transport capacity leads to immediate deposition of bed-load though suspended-load responds gradually The distance eroded particles travel depends primarily on their size, density, shape and the velocity of the runoff water Coarse sand particles in eroded soil move the shortest distance and settle out first Fine sand and silt drop out next as runoff water slows down Some very fine silt drop out only in standing water Very fine clay and colloidal humus will not settle out even in still water but stays suspended indefinitely Generally, the bulk of eroded material from hillsides comes to rest at the foot of slopes or on nearly flood plains.

Factors affecting soil erosion

(1) *Rainfall* The rainfall to be effective for erosion, must have an intensity higher than the infiltration rate of the soil A combination of low intensity rainfall and high permeable soil may not cause any soil erosion, as there may not be runoff If the soil is very dry and a high intense storm occurs for a short period, then also erosion may not occur If the antecedent moisture condition is high, and is followed by a heavy rainfall, high rate of runoff and consequently severe erosion may take place (details are given in Chapter 4)

(2) *Topography* The topography of the land has definite effect on the runoff and soil

loss. The main topographical factors are· degree of slope, length of slope and curvature of slope.

(i) On level land, soil erosion is usually negligible. In such areas deposition (sedimentation) may be a problem rather than soil removal. Generally as slopes get steeper, erosion increases. Sandy soils, which have little erosion at slight slopes, are subject to a high degree of erosion on steep slopes. All soils on steep slopes (over 10%) are subject to erosion with net movement in a downhill direction Slope steepness influences erosion in several ways The increased velocity of runoff water allows more soil to be picked up and transported. Surface detention of water becomes less as slope increases because of decreased capacity of furrows or depressions. Also, the film of water that forms over level soils during an intense rainfall, which also helps to dissipate rain drop energy, cannot form on steep slopes.

(ii) The relationship between soil loss and slope length is approximately equal to the the square root of the slope length On soils that crack when dry, the value of the slope exponent may approach zero On soils, where runoff increases with slope length, the exponent is greater than 0.5 As water flows down a slope more soil is lost from the lower part than from the upper part The obvious way to reduce erosion from long slopcs is to break them into segments

(iii) Slopes may be roughly convex or concave. Convex slopes increase in steepness toward the bottom Thus, runoff velocity also increases toward the bottom of the slope On convex slopes, there is no deposition, only removal of soil takes place Concave slopes flatten out toward the bottom of the slope and sediment carried in runoff water settles out as flow velocity decreases. With intense rains and high velocity flows, however, water may concentrate in concave slopes and start gully formation If gully formation does not occur, then the area accumulates high organic matter surface soil and becomes more fertile As per Mannig's or Chezy's flow formula the velocity of flow increases in proportion to the square root of the slope That means increasing the slope by four times, increases the velocity by two times Then the kinetic energy increases by four times and 32 times more material can be transported The length of slope influences the soil erosion to a lesser degree The kinetic energy of flow is proportional to the square root of the length of slope

(3) *Soil surface cover*· Vegetation plays a major role in retardation of soil erosion and conservation of *in situ* moisture Part of the rain is intercepted by the leaves and branches of trees and evaporates directly to the atmosphere Thus, the surface runoff is reduced. Also due to the transpiration through the leaves, the storage capacity of the soil increases and infiltration rate increases Vegetation absorbs part of the energy of raindrops and the force of impact on the soil surface reduces Vegetation cover retards the surface velocity of runoff water and transportation capacity reduces. The root system of the plants acts as binding agent for the soils and the detachability reduces The decaying of roots, leaves, etc , increases the porosity of soil and the capacity to absorb water increases. Addition of humus through decaying roots, leaves etc , creates a favourable condition for absorption and holding of more moisture inside the soil Thus, vegetative cover helps to conserve both soil and moisture in numerous ways

(4) *Soil*: Soil properties that influence erosion are soil texture, bulk density, organic matter content, moisture content, etc. Soil texture and structure affect the infiltration and percolation rates of soil For a light textured sandy soil a low intensity rainfall may not produce any runoff and therefore, there will not be any erosion. But there is not much binding force among the particles in such type of soil and therefore, detachability is high. However, if the velocity of runoff is not high, sand particles cannot be transported. In case of fine-textured clay soil, infiltration capacity is low and high runoff takes place. But the binding force in clay soil, specially with high organic matter content is large compared to other soils. Therefore, the particles cannot be easily detached unless the high intense rain strikes bare soil. But once detached, the particles can be easily transported. Very fine textured soils are more susceptible to erosion. Medium textured loam or fine sandy loam soils are least susceptible to erosion.

(5) *Biological factors*: Biological factors that influence the soil erosion are the activities like felling of trees, faulty cultivation practices, overgrazing by cattle etc. Without such activities, the soil, climate, vegetation, etc., will remain in a balanced condition and no erosion will take place.

(6) *Incorporated residue*: The crop residue every year builds and maintains the soil's organic matter, which controls soil loss Large pieces of mulch material like corn stalks and slash on disturbed forest lands can reduce rill erosion by acting as grade control structures.

Types of soil erosion

Water erosion

There are two major types of erosion, namely, geologic and accelerated They represent contrasting types of soil removal In its broadest sense, geologic erosion is a normal process, representing erosion of land in its natural environment without the influence of rain. It is caused mainly by the action of water, wind, temperature variations, gravity and glaciers It has been responsible for the wearing away of hill and hillocks and the cause of present land surface features. The rate of this erosion, combined with the complex processes of soil formation, largely determines the kind of soil that has developed and its distribution. Accelerated erosion is in excess of geologic erosion and is induced by man's activities which have brought about changes in natural cover and soil conditions. It is usually caused due to man's activities when preparing land for the production of food and fibre and as a place to build houses, infrastructure and industries Unless measures are taken to guard against such destructive erosion it becomes the most potent single factor contributing to deterioration of productive soil (Plate 5)

Water erosion is the main cause of soil erosion Soil particles are detached either by raindrop impact or by flowing water (Figure 3 1)

(a) *Raindrop erosion* Raindrop or splash erosion results from soil splash caused by the impact of falling raindrops Individual raindrops strike the soil surface at velocities upto 9 m/s, creating very intense hydro-dynamic forces at the point of impact (Mutchler and Young, 1975) Consider that the number of raindrops during a rainstorm may be as high as several millions per square metre the cumulative impact of rains in detaching soil particles is tremendous Quite easily, raindrop impact detaches more sediment than overland flow on short slopes (Ellision, 1947, Foster, et al , 1977) When the raindrop strikes

Plate 5 *Sheet erosion on agricultural plots is a gradual process Life support topsoil is first to be washed away.*

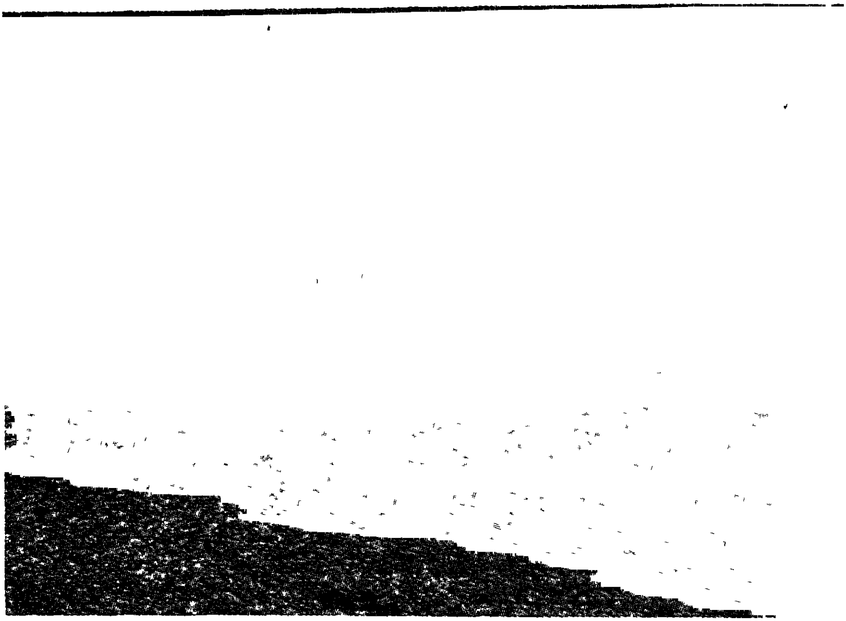


Figure 3.1 *Factors influencing erosion*

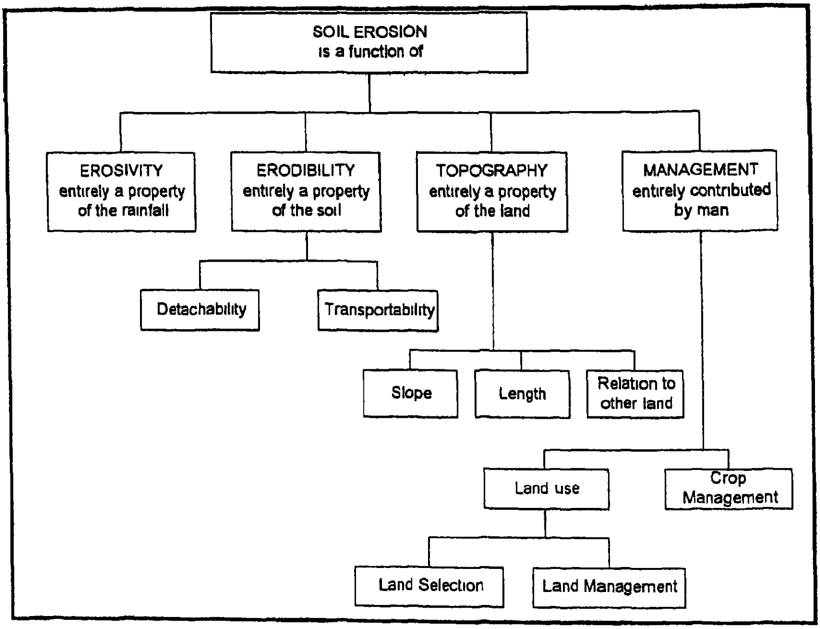
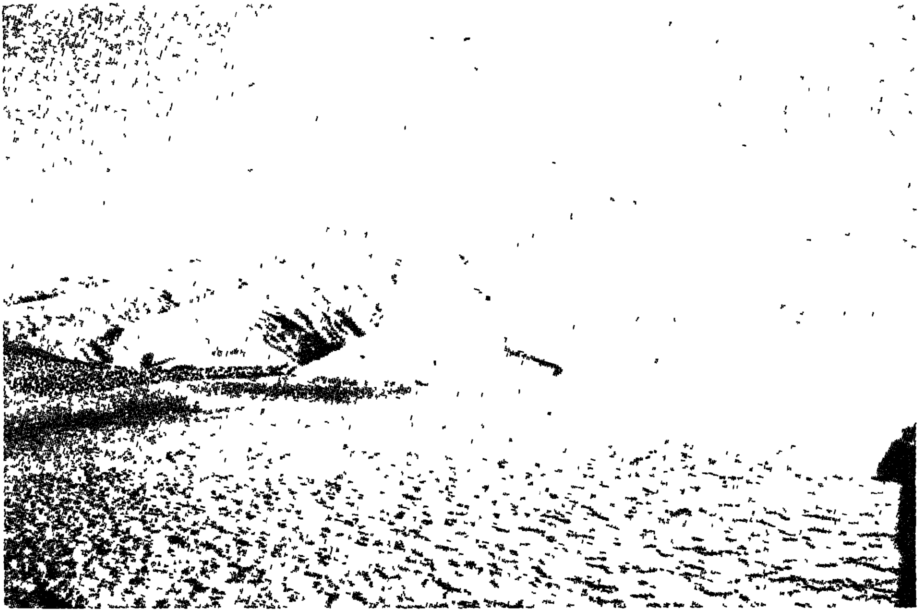


Plate 6 *Denuded hills and hillocks suffer from rill erosion mainly due to raindrop impact and lateral transport of detached particles*



the bare soil, considerable raindrop erosion takes place A good cover of vegetation breaks the drops into finer sprays and most of it infiltrates into the ground Sometimes, the raindrops fall at high speed of 50 kmph, then the soil particles may be splashed to a height of 60 cm and laterally to a distance of 150 cm The same soil particles are generally splashed more than once. On a level surface, serious problems may not arise, as the soil gets shifted from one place to another On the other hand, in sloping lands, they are easily transported down the slope and may join a rill or gully from where further downward movement becomes easier The raindrops also wash away numerous nutrient ingredients of soil thereby reducing the fertility of soil A part of the rainfall with clay and silt suspension infiltrates into the ground In this process, the fine particles are removed due to stirring and sedimentation phenomena These fine particles block the soil pores, and the infiltration capacity of the soil is greatly reduced Thus, raindrop damage increases with the duration Factors affecting raindrop erosion are vegetative cover and mulches, rainfall, wind velocity and direction, soil texture and structure, topography especially degree and length of slope (Plate 6)

(b) *Sheet erosion* It is the uniform removal of soil in thin layers from sloping land, which usually results from sheet or overland flow occurring in their layers Initially, the top layer of the soil gets slowly scummed off every year and flows down the slope as muddy layer The soil loss in such a fashion is quite inconspicuous, but over a period of time the crop yield decreases. Sheet erosion results in exposing bedrock with continuous depletion of soil Results of sheet erosion often appear as light-coloured patches of soil on hillsides Dark-coloured soil, with its characteristic organic matter content, on being washed away, exposing the organic-matter deficient, light coloured subsoil. Two basic erosion processes are involved in sheet erosion. first, the soil particles are detached from the body of the soil, and second, the particles are transported away from their original location. The flowing water may move as a thin sheet across the soil surface. This is called *sheet flow* It can result into significant soil loss from a given area. The eroding and transport power of sheet flow are functions of the depth and velocity of runoff for a given size, shape, and density of soil particle or aggregate. Although, sheet erosion occurs slowly but it is very harmful as it cannot be detected easily in the initial stage

(c) *Inter-rill erosion*· Though, overland flow is usually analyzed as a broad sheet flow, erosion processes on inter-rill areas are primarily detached by raindrop impact and lateral transport of detached particles to the rills by their overland flow plus particle entertainment by raindrop impact. Transport by direct splash to the rills is minimal (Young, 1973). The downslope sediment transport is by flow in the rills. The detachment and transport processes on the inter-rills area occur essentially independent of rill erosion. Sediment from inter-rill area is eroded from a very thin surface layer of soil This sediment is usually a mixture of primary particles (sand, silt and clay) and aggregates (conglomerates made up of primary particles). Due to selective sorting and greater particle breakdown owing to repeated raindrop impact after detachment, particles from inter-rill areas tend to be smaller.

(d) *Rill erosion*. Sheet flow over the soil surface occurs mainly when the surface is smooth and of uniform slope. But, in reality, there tend to be low places and high places, there are irregularities between soil clods and aggregates of different sizes and those caused by human/cattle interventions So, the water tends to accumulate in depressions and begins to flow, taking the path of least resistance Essentially, flow hydraulic in the terrain, the susceptibility of the soil to detachment by flow and the transportability of the detached sediment decide the process of detachment and transport in rills. Flow in rills detach soil particles when the flow's transport capacity is more than its sediment-load Sheer stress of the flow detaches the soil particles The process includes head cutting, undercutting, soughing off the sidewalls, cleanout of the slumped material, scour and transport of detached particles etc. Rill erosion is usually non-uniform with high rates at the headcuts. The dimensions of the headcut depends upon the flow, soil qualities and slope The primary particle size of rills sediments are generally similar to those of the original soil mass. Rill are formed as soon as surface flow begins. They vary in size from minute channels to a size that is easily observed The number of rills that develop in a given area can vary widely, depending on the irregularity of the soil surface and the amount and velocity of runoff When the pattern of rills has developed, sheet erosion is confined mainly to the smooth surfaces between rills Detachment and transportation of soil particles are both greater in rill erosion than in sheet erosion In rill erosion, detachment is primarily by the energy of flowing water, not by raindrop impact as seen in sheet erosion Rill erosion removes some topsoil, but once the rills are formed much of the cutting is downward and may extend into the subsoil During deposition, the denser and larger particles are deposited first Generally, bed-load deposition and suspended-load deposition occurs on upland and down stream zones of the rill respectively Rill erosion is most severe where intense storms occur on soils with high runoff characteristics and where the topsoils erode easily

(e) *Gully erosion* Gully erosion is an advanced stage of rill erosion It occurs on a bigger scale than rill erosion. The cross-sections of gullies frequently assume a V or U shape. The V-shaped cutting because of fine soil texture or toughness. The U-shaped gullies are often found in alluvial valleys where both the surface soil and subsoil are easily eroded. It is not uncommon to find both V and U shapes in the same channel. Often, gullies are started as tracks made by movement of unattended livestock. Rills get deepened and widened every year to attain the form of gullies The side slopes of gullies in many soils fall and big blocks of soil mass get sloughed into the flow The flow through the gullies transports away such soil material The channel erosion takes place all along the length of the gully. The channel erosion interacts strongly with the incoming sediment load. These channels may act as major sinks for sediments during periods of excessive upland erosion. When the upland supply is exhausted, the previously stored sediment may erode with large sediment yield rates continuing for several years (Trumble, 1975). The rate of gully erosion depends primarily on the runoff producing characteristics of the watershed—the area, soil characteristics, the alignment, size and shape of gully, slope of gully and the slope of the channel. Gully erosion often follows sheet and rill erosion. It usually occurs, either where runoff from a slope increases sufficiently in volume or velocity to cut deep incisions, or where the concentrated water flows long enough in the same channel to develop deep incisions

Gully development occurs in four stages·

Stage-I (Formation stage)· Scouring in the bottom or on the sides of the gully by flowing water plus any abrasive material, such as soil particles or debris carried by the water

Stage-II (Development stage). Upstream movement of the gully head and enlargement of the width and depth of gully Slides or mass movement of soil into the gully from the sides, caused by the lubricating action of seepage, alternate freezing or undercutting by channel flow.

Stage-III (Healing stage). Vegetation cover starting to grow in the channel.

Stage-IV (Stabilisation stage) Gully forms a stable gradient The gully walls reach a stable slope and the vegetative cover spreads over the gully surface (Plates 7 and 8)

(f) *Stream erosion·* It is the scouring of material from the water channels and the cutting of banks by running water. Such erosion takes place usually at the lower end of head-water tributaries and to streams that have a nearly continuous flow and relatively flat gradient. Stream banks get eroded very distinctively by runoff flowing over the side of the stream bank, scouring or by under-cutting Scouring is influenced by the velocity and direction of flow, depth and width of channel and soil texture

(g) *Landslide erosion.* Water weakens the inter-particle cohesive force in the soil on steep hill slopes, as a result the soil yields to gravity and slides down as landslide

Wind erosion

In India, wind erosion has been primarily responsible for creation and maintenance of the vast desert area of Rajasthan It is a very serious problem in arid and semi-arid regions It may take place in humid areas as well The sandy soils along the rivers, lakes and coastal plains may be removed by wind erosion. The finer soil particles from the topsoil alongwith organic matter and nutrients are easily detached and removed Coarse-textured soil particles remain, which are not favourable for vegetation and waterholding capacity reduces The erosion increases further Numerous factors affect the wind erosion, viz, wind, rain-

Plate 7 *Rills on hillocks and undulated terrain become deep and wide Over a period of few years gullies are formed*

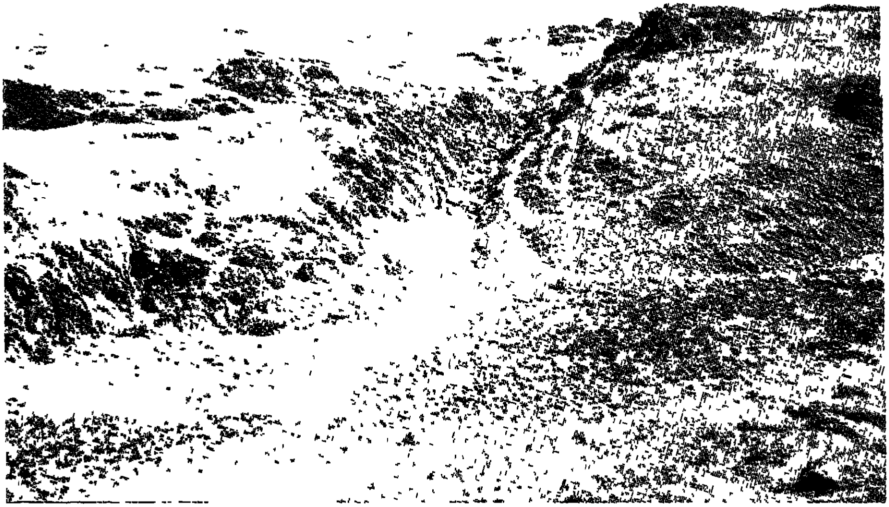
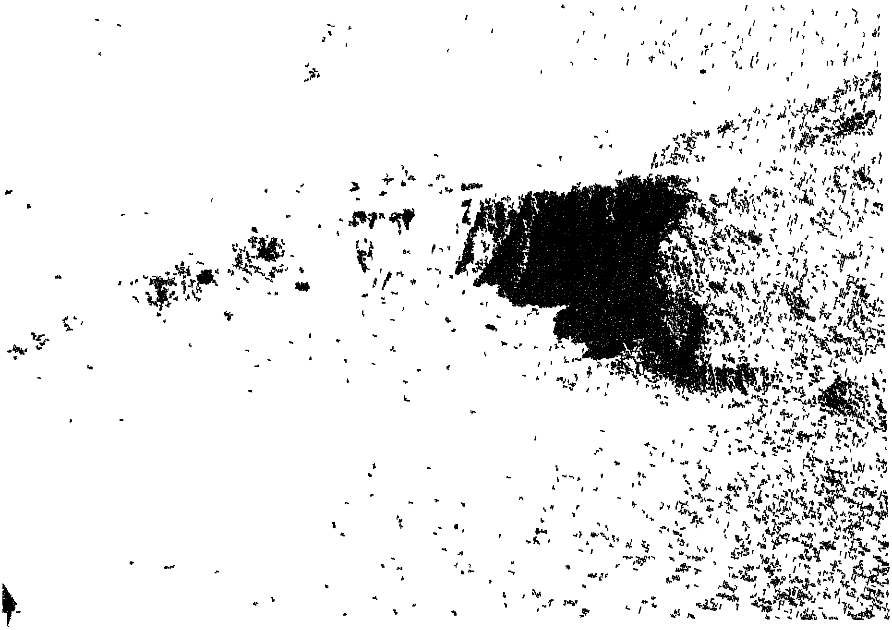


Plate 8 *Uncontrolled gullies may turn into ravines, which is a major ecological threat*



fall, temperature, humidity, soil factors like texture, structure, organic matter content, water holding capacity, bulk density, coverage of the area by vegetation and height, density and distribution of vegetation The wind erosion process occurs in three different stages·

Stage-I (Initiation movement): The minimum velocity of wind required to initiate movement of a given size of soil particles is known as *threshold velocity* For example, a lowest threshold velocity of 13 to 15 kmph at a height of 15 cm above the ground is required for particle diameter in the range of 0 1 to 0 15 mm. The threshold velocity for soil particles covered with crop residues, grasses and vegetative cover is higher than the bare fields or hillocks. The threshold velocity varies in the range of 20 to 50 kmph at a height of 30 cm above denuded smooth ground surface The minimum velocity required to continue soil movement under this condition is called *dynamic threshold velocity*

Stage-II (Transportation of soil): Eddies and cross-currents are responsible for lifting and transportation of soil particles. The amount of soil transported depends upon the particle size, distribution of different size particles, wind velocity and the distance across the eroding area. Generally, huge quantity of soil having 0 1 mm diameter can be transported by wind Most of the soil movement takes place within a height of 60 to 90 cm. The deposited particles have diameter in the range of 0.16 to 0 35 mm On sandy soils, major movement takes place along the surface of the ground and fine particles constitute a negligible part of the volume of soil movement

Stage-III (Deposition of soil) With the reduction in the wind velocity, transported soil particles get deposited. Different approaches and techniques should be adopted by PIA in watershed areas to control and check soil erosion.

Cost of soil erosion

The damages of soil erosion can be partitioned into costs on the site where soil erosion is taking place and off the site where sediment deposition takes place Following are the major damages of soil erosion·

(a) *Loss in production potential* It has been estimated that the soil loss from erosion in India is around 5334 million tons In other words 16 35 tons/ha/year soil loss is taking place. As mentioned earlier, topsoil or the most productive layer of the soil is most susceptible to erosion All kinds of soils suffer a decline in productivity with erosion The effect of soil loss on production varies, depending upon the type and depth of the topsoil Some soils virtually become useless for crop production, when seriously eroded

(b) *Reduction of infiltration rates* With the erosion of the topsoil the remaining subsoil cannot absorb the rainfall rapidly Consequentially, there will be more runoff Due to erosion, there will be less soil available for moisture storage

(c) *Reduction in water-holding capacity* Soil loss directly leads to reduction in moisture retention and water holding capacity

(d) *Loss of nutrients* It has been estimated that the soil eroded from farms and forest lands each year has an average analysis of 0 1% N, 0 15% P and 1 5% K (Taylor, 1966) Extrapolating this, the nutrient loss from 5334 million tons would cost billions of rupees This has to be furnished every year by artificial spraying of fertilisers This would cost thousands of rupees per hectare

(e) *Increase in tillage operations costs* With washing away of topsoil, more efforts are required for tillage of subsoil It becomes, over a period of years, more difficult to prepare an adequate seedbed. Crop germination and yields are also adversely affected. In dry periods it is more difficult to get good seed-soil contact on eroded soil. And in wet periods, aeration is a problem on eroded soil. Tillage operations could be possible only for a restricted period, as the moisture retention capacity of the subsoil drastically reduces Gullies within the field may be nuisance resulting in decrease in production and productivity. In fact, fields may be so much cut up with gullies, that farming becomes impractical on such lands.

(f) *Reduced transport and storage capacity*: Deposition of sediments in stream channels reduce their capacity and causes them to overflow their banks frequently. Due to the loss of storage of reservoirs by sediment deposition, the design and maintenance of such reservoirs become difficult. Numerous smaller ponds and reservoirs become essentially useless in a relatively short time (Table 3.1)

Table 3.1 *Annual sediment deposition in some major reservoirs (acre-feet)*

Sl No	*Reservoir*	*Expected rate*	*Actual rate*
1	Bhakra	23,000	33,475
2	Maithan	684	5,980
3	Mayurakshi	538	2,000
4	Nizamsagar	530	8,725
5	Panset	1,982	9,533
6	Ramagunda	1,089	4,366
7	Tungbhadra	9,796	41,058
8	Ukai	7,448	21,758

(g) *Reduction in water supply*. Large investments may be required in the construction and operation of treatment facilities to remove the sediment. Silt increases the wear on pumps and equipment and sediment deposition in storage basins increase the maintenance cost

(h) *Depletion of wildlife*· The removal of the topsoil makes the survival of the wildlife more difficult The sediments in streams, lakes, reservoirs, estuaries, etc, destroy the natural habitat for aquatic wildlife. Suspended sediments impair the dissolved oxygen-balance and obscure the light essential for aquatic growth Thus, they are detrimental to aquatic life Heavier sediments cover fish-spawning areas and food supplies

Estimation of soil loss

Several equations are available to estimate soil loss. The most commonly accepted equation is Universal Soil Loss Equation (USLE), which is developed by Wischmeier and Smith (1978) It estimates average annual mass of soil loss per unit area as a function of most major factors effecting sheet and rill erosion.

Universal soil loss equation (USLE)

The USLE is designed to predict the long-term average soil losses from a specified land in a specified cropping and management system It predicts, essentially the losses from sheet and rill erosion under specified conditions. It enables to determine the land management, erosion rate relationship for a wide range of rainfall, soil, slope, crop and management conditions It helps in selection of alternative conservation agronomics, forestry or structure management combinations.

The USLE is thus

A = R. K. L. S C. P.

Where:

A= The computed soil loss (in tons/ha/year).

R= The rainfall factors (it is the number of erosion index (EI) units during the period under consideration). The erosion index is a measure of the erosive force of specific rain.

K= The soil erodibility factor and is the soil loss per erosion index unit for a specified soil as measured on a unit plot (it compares the actual erosion to the erosion from a clean, tilled, fallowed, uniform slope of 9% and length of 22.13 m)

L= The slope length factor (it is the ratio of soil loss from the field slope length to that from a 22 13 m length on the same soil type and gradient).

S= The slope steepness factor (it is the ratio of soil loss from the field slope gradient to that from 9% on the same soil type and gradient).

C= The cover and management factor (it is the ratio of soil loss from an area with specified cover and management to that from a identical area in tilled continuous fallow).

P= The erosion-control practice factor (it is the ratio of soil loss with a support practice like contouring, strip-cropping or terracing to that with straight-row farming up-and-down the slope.

Knowing the values of rainfall factor, soil erodibility factor and slope, one can calculate the soil loss The values of K, L, S, C and P are available in all standard SWC textbooks The equation is simple but in most developing countries, the available data is insufficient to evaluate most of the components of the equation. The rate of erosion should consequently be based on the more conventional methods of research. So, conventional methods should be used to asses the severity of erosion on various soil, slope and management practices

4

Land Capability Classification

Land capability classification is the basis of watershed management The basic theme of SWC in watershed management is to use the land according to its capability and treatment of the land according to its needs Thus, knowledge of land capability classification is a prerequisite and important for planning, implementation and evaluation of SWC measures in integrated watershed development programme It is defined as a systematic arrangement of different kinds of land according to those properties that determine the ability of the land to reproduce on a virtually permanent basis A comprehensive land use policy should be based upon land capability classification Policies and proposed measures for command area, catchment, reservoirs, etc., should focus on the specificities of the land Following are the objectives served by land capability classification

(i) It indicates the hazards of soil and water erosion and difficulties to be encountered in land use accordingly.
(ii) It involves most intensive, profitable and safe use on the available land
(iii) It simplistically provides technical data and indicators for application to land use planning.
(iv) It enables the cultivators to make the use of techniques and inputs available for agriculture as scientific and technical information is available for each class of land

Land is arranged in various capability classes after considering a number of soil characteristics, associated land capabilities classes which are. soil texture, effective soil depth, permeability, internal drainage, soil salinity, alkalinity and toxicity, coarse soil fragments, slope of land, effect of past erosion, natural soil drainage, frequency of overflow, etc Due consideration has to be paid to type (water, wind, gravity), form (sheet, rill, gully) and severity (e1, e2, e3, e4) of erosion for classifying land into various classes Climatic factors like rainfall, temperature and wind velocity are important components for classification

There are two broad groups, namely

(i) Lands suitable for cultivation (Class I to IV lands), and
(ii) Lands not suitable for cultivation, but suitable for forestry, grassland and wildlife (Class V to VIII lands)

Land capability classification

These classes are groups of capability sub-classes or capability units that have the same relative degree of hazard or limitation. The risk of soil damage or limitation becomes progressively higher from class I to VIII The land capability classes are mapped as roman numbers, e.g , I, II, III, IV, etc

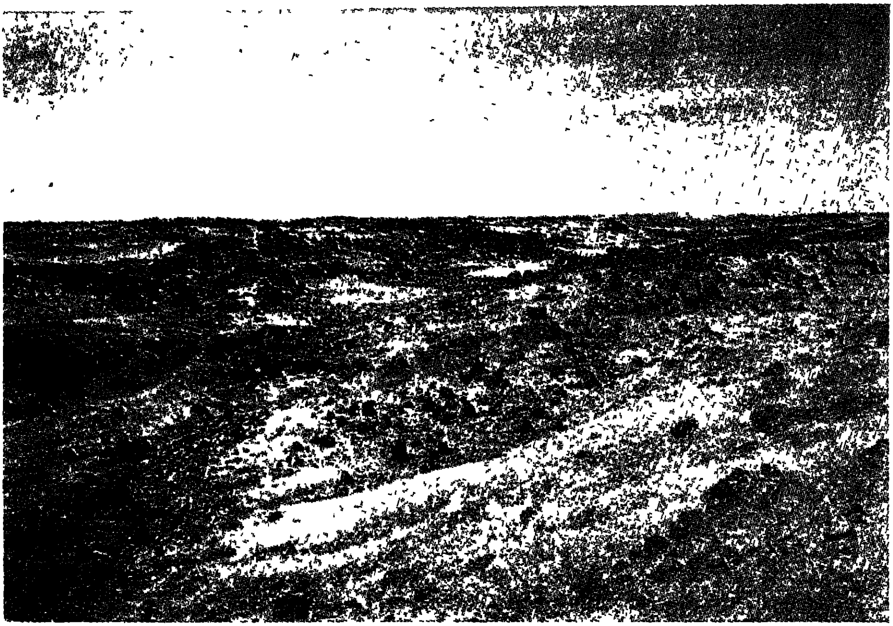
Land capability sub-classes provide information about the kind of conservation problem or limitations involved Sub-classes are essentially groups of capability units having the same major conservation problems, such as e-erosion and runoff, w-excess water, s-root zone limitation, c-climatic limitations. These are suffixed to the roman letters (depicting land capability classes) by alphabets, e g., Ie (erosion and runoff), IIw (excess water), etc

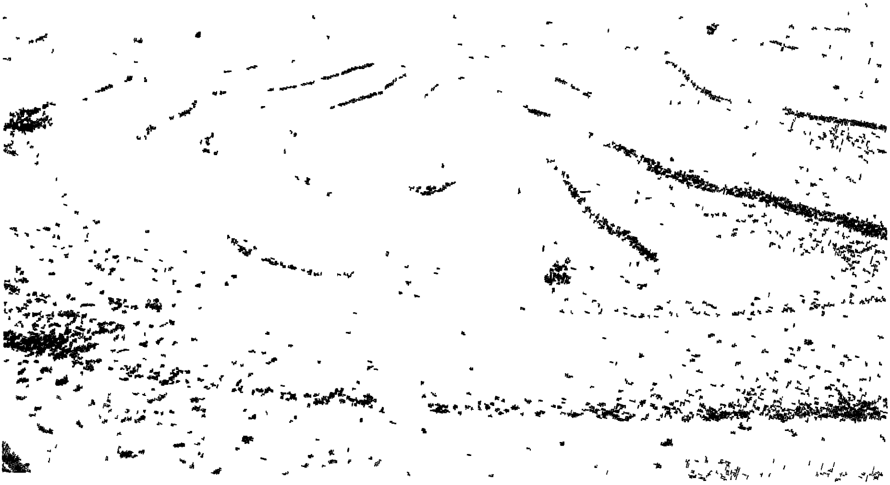
Land capability units are groupings of one or more individual soil-mapping units having similar potentials and continuing limitations and hazards Land under same capability units produce similar kinds (and quantities) of cultivated crops/pastures/plants, with similar management practices require similar conservation measures under the same kind and condition of vegetative cover and have comparable potential of productivity. They are represented as ordinary numerals placed as subscripts to the sub-class letters in the capability notation. The numerals represent following meanings·

(1) limitations of effective soil depth, (2) very heavy or light texture of soil, (3) nature of material restricting root zone, (4) salinity or alkalinity of soil, e g , IIw1, IIw2, IIIw3, IIw4, etc The land capability classes and their basic salient features are depicted in Table 4 1 (see Plates 9, 10 and 11)

Plate 9 *Land capability classification is not very difficutl to ascertain Even a layman can differentiate the land capabilities and degradation in a watershed area Different strategies should be adopted foı different land classes*

Plates 10, 11 *Land capability classification is not very difficutl to ascertain Even a layman can differentiate the land capabilities and degradation in a watershed area Different strategies should be adopted for different land classes*





ble 4.1 *Land capability rating table*

	Class I	*Class II*	*Class III*	*Class IV*	*Class V*	*Class VI*	*Class VII*	*Class VIII*
Colour on map	Green	Yellow	Red	Blue	Dark green uncoloured	Orange	Brown	Purple
Degree of limitations for use	Few	Moderate	Severe	Very severe	Few	Moderate	Severe	Very severe
Soil characteristics (a) Texture	Loams	Loams	Clay and loams sands	Clay and sand	No limitations of soil texture, soil depth etc except that the soils are rocky	No limitation of soil texture, soil depth etc except that the soils are rocky	Soil limitations are more severe than those in class VI	Soil and land in this class cannot be used for commercial plant production but should be conserved for wildlife watershed protection conservation forestry
(b) Soil depth (cm)	Very deep > 90	Deep 45-90	Moderate 22 5-45	Shallow 7 5-22 5	Very deep	Very shallow < 7 5	Very shallow < 7 5	Rock, very shallow
(c) Permeability	Moderate	Moderate slow modrate rapid	Slow rapid	Very slow very rapid				
Associated features (a) Slope	Nearly level (1%)	Gentle (1-3 %)	Moderate (3-5 %)	Strong (5-15 %)	Nearly level (< 1%)	Steep (15-25%)	Very steep (> 25%)	Precipitous
(b) Effect of past erosion or susceptibility to erosion (wind or water)	None to slight sheet erosion (e1)	Slight sheet erosion(el)	Moderate rill erosion(e2)	Severe small gullies(e3)	None to slight (e1)	Very severe gullied land or sand dunes (e3)	Very severe gullied land (e3)	(e4)
(c) Drainage	Wetness	Wetness which can be corrected by drainage	Excessive continues after drainage	Excessive wetness	Excessive wetness	Excessive wetness	Excessive wetness	Wetness
(d) Damaging runoff	None	Occasional	Frequent with some damage	Frequent with damage	Frequent over runoff	Excessive runoff	Excessive runoff	Excessive runoff
Climatic limitation on soil use and management	Favourable for growing many common field crops	Slight limitation for field crops	Moderate limitation for field crops	Moderately adverse for field crops	Adverse for field crops	Adverse for field crops	Adverse for field crops, require protection	Adverse for field crops, require protection conservation

Soil and land capability-suitability surveys

Three basic surveys are required for rationalising land use, soil survey, slope analysis and land capability-suitability classification

Soil survey

This manual does not describe the different procedures of mechanical and chemical soil analysis, but general remarks are included for application in watershed planning.

If a standard soil survey results are already available then only supplemental data is required There would be a need for soil survey only when it has not been done in the past

(a) *Standard survey*: It should usually include identification of major soil types and boundaries, recognition of problem soils, information regarding soil depth and location of limiting factors (like waterlogging, erodibility etc), information on soil nutrients, moisture, rootzone condition.

(b) *Supplemental survey* When a standard soil survey exists, supplemental soil survey may be needed. The vital information missing in standard survey should be collected Usually land-literacy campaign or plot-to-plot survey method is used.

(c) *Soil survey by traverse method.* This method consists of examination, classification and mapping of soils in the field-by-field method The soils are examined at regular intervals The soil boundaries are demarcated and the area is delineated into different mapping units and in each unit soil profiles are studied in detail. This method can easily be used in watershed areas.

Additional features like colour, salinity, fertility, moisture capacity, undulation, etc , can also be gathered Soil samples may be collected for laboratory investigation for pH, EC, available nutrients and mechanical analysis.

(d) *Soil survey by aerial photo-interpretation* Various characteristics could be analyzed from photo interpretation Following features could easily be interpreted

— Degree, direction, type and length of slope.
— Soil texture.
— Broad land use classes (e g , wasteland, cultivable land, grazing land, forest land, etc).
— Size, pattern and density of drainage
— Location, size, extent and shape of erosion
— Soil fertility.

These features could be analyzed from shape, size, tone, texture, shadow and pattern of images The information from aerial photos should be correlated and verified with the help of field checks

If, however, no such soil surveys are carried out, the following subjects would have to be recorded to make a land use suitability classification possible. Furthermore, the existing pattern of agricultural production and the climax vegetation would be of importance in land evaluation and possible land use.

Different soil characteristics and land features are noted in the fields The fundamental ones are soil depth (Table 4 2), soil texture (Table 4 3), soil permeability (Table 4 4), land slope (Table 4 5), and soil erosion phases (Table 4 6)

Table 4.2 *Soil depth classes*

Symbol	*Name*	*Depth Range (cm)*
d1	Very shallow	0-7 5
d2	Shallow	07 5-22 5
d3	Moderately deep	22 5-45 0
d4	Deep	45 0-90 0
d5	Very deep	> 90 0

Table 4.3 *Soil texture classes*

Sand	0 05-2mm	Particles visible
Silt	0 002-0 05mm	Particles hardly visible
Clay	< 0 002 mm	Particles not visible
Clayey soils	> 50%	Clay particles
Silty soils	> 50%	Silt particles
Sandy soils	> 50%	Sand particles

Table 4.4 *Soil permeability classes*

Symbol	*Permeability class*	*Rate of flow(cm/hr)*
1	Very slow	< 0 13
2	Slow	0 13-0 5
3	Moderately slow	0 5-2 0
4	Moderate	2 0-5 0
5	Moderately rapid	5 0-13 0
6	Rapid	13 0-25 0
7	Very rapid	> 25 0

Table 4.5 *Land slope classes*

Symbol	*Slope class*	*Slope %*
A	Nearly level	0-1
B	Gently sloping	1-3
C	Moderate sloping	3-5
D	Strongly sloping	5-10
E	Moderate steep	10-15
F	Steep	15-25
G	Very steep	25-33
H	Very very steep	> 33

Table 4.6 *Soil erosion/phase*

Symbol	*Erosion*	*Characteristics*
e1	Not apparent or slight(sheet)	0-25% top soil or original plough layer within a horizon removed
e2	Moderate (sheet and rill)	25-75% top soil removed
e3	Severe (sheet, rill and small-gullies)	75-100% top soil and upto 25% sub-soil removed
e4	Very severe (shallow gullies)	Gullied land
e5	Very, very severe (shallow gullies)	Very severely gullied land or sand dunes

Slope analysis

Circle Interception Method is most commonly used for slope analysis Distances in all directions of the circle are equal Thus, it represents a fixed horizontal distance on the ground Contiguous circle sheet is overlaid on a topographic map and contour intervals in each circle are counted, which give the values of the vertical rise. The slope of a circle is determined by:

$$\text{Slope } \% = \frac{\text{Vertical rise}}{\text{Horizontal distance}}$$

Circle sheets used are transparent films printed with contiguous circles of 8 mm (which on 1 10,000 map represent 250 ft). This is imposed on 1:10,000 and 7.5 m contour topographical map. The contour intervals intercepted by each circle are counted The slope category of each circle can be determined from slope analysis graph Each circle is given a proper colour based on the slope range A draft slope map may be produced by grouping the same coloured circles on another overlay. This map should be carefully superimposed on the original topographical map for checking Spot checks in the field should be undertaken at several points in the watershed A final map should be drawn for each topographical unit. Slope analysis can be done by using areal photographs and stereovision

Land capability and suitability classification

Though, capability and suitability are exchangeable, the former's primary consideration is to prevent land degradation and the latter's is to consider the fitness of a given type of land for a defined use. Soil map should be put on a coloured slope category map Every slope category should be considered as a unit considering soil depth and other limiting factors. Following checklist may be used

(i) Regardless of soil depths and other limiting factors
   Slope 7 classifies to FP (Protection of forest) Slope 6 classifies to F (Forest land)

(ii) Where soils are deeper than 90 cm (36") and there is no soil limiting factor, the classification is straightforward as follows
   Slope 5 classify to FT (For fruit or food trees)

Slope 4 C4 (Cultivable land 4).
Slope 3 C3 (Cultivable land 3).
Slope 2 C2 (Cultivable land 2).
Slope 1 C1 (Cultivable land 1).

(iii) Regardless of soil depth, where soils have limiting factors preventing normal tillage, i e , too stony, too wet, frequent flooding and severe gully dissection, the classification is as follows:
Slope 5 F (Forest Land).
Slope 1,2,3,4: P(Pasture)

(iv) Where· (1) soils are shallower than 90 cm (36"), and (2) without soil limiting factors, the classification will be done as follows:
Slope 5. AF (soil depth not enough for 1 75 m wide orchard terraces) FT (enough foi above treatment)
Slope 4 P (soil depth not enough for 2 m wide hillside ditches) C4 (enough for above minimum treatment)
Slope 3. P (soil depth not enough for 2 m wide hillside ditches C3 (enough for above minimum treatment)
Slope 2: P (soil depth not enough for 2 m wide hillside ditches C2 (enough for above minimum treatment)
Slope 1 P (soil depth below 15 cm) C1 (soil depth above 15 cm)
(AF Agro-forestry, FT Forestry, P Pasture, C1-C2 Cultivable land)

Limitations

Land capability and suitability classification is not very appropriate in Indian conditions due to different socio-economic conditions, land use patterns, etc Land slopes have not been classified and are rated on the basis of length and type of slope (continuous or terraced) The productivity of the terraces, the socio-economic condition, population and political pressures may not allow the use of even C1 land The size and percentage of coarse texture in different textural classes do not find representation in the system. Some of the soil parameters like, degree and type of erosion, salinity, alkalinity, climate, etc., are not well defined Similarly, the ranges of the parameters are very limited and may not find proper place in land capability classes Effect of local environment, e g , proximity to forest has not been taken into consideration Suitability of land for local and indigenous crops has not been considered as a criterion for land capability

Recommended practices for different land classes

The soil and water conservation farm practices suited for class I to IV lands are given in Table 4 7 Each class of land may need one or more of the practices, depending upon the prevailing conditions of farming

Soil and water conservation practices suited for class V, VI to VII lands are depicted in Table 4 8. Each class of land may need one or more of the above practices depending upon the prevailing conditions

Table 4.7 *Selection of soil-and-water-conservation farm practices for land suited for cultivation (for class I to IV)*

	Class I	Class II	Class III	Class IV
Good farming				
Fertilising	yes	yes	yes	yes
Manuring	yes	yes	yes	yes
Liming, if necessary	yes	yes	yes	yes
Cover cropping	yes	yes	yes	yes
Green manuring	yes	yes	yes	yes
Crop rotation	yes	yes	yes	yes
Conservation crop residues	yes	yes	yes	yes
Simple soil and water conservation practices				
Contour cultivation	no	yes	yes	yes
Contour strip cropping	no	yes	yes	yes
Stubble mulching	no	yes	yes	yes
Contour terraces (bunds)	no	yes	yes	yes
Graded terraces (bunds)	no	yes	yes	yes
Intense soil and water conservation practices				
Bench terracing	no	no	yes	yes
Drainage	no	yes	yes	yes
Reclamation of saline and alkali soils	no	no	yes	yes
Ley farming	no	no	no	yes

Table 4.8 *Selection of pasture and forest management practices for class V, VI and VII lands*

	Class V	Class VI	Class VII
Pasture management			
Seeding	yes	yes	yes
Fertilising	yes	yes	limited return
Liming when necessary	yes	yes	limited return
Controlling water	no	yes	difficult
Attention to carrying capacity	yes	yes	limited grazing
Rotational grazing	no	yes	limited grazing
Deferred grazing	no	yes	limited grazing
Fencing	no	yes	yes
Location of watering places	no	yes	yes
Forest management			
Plantation	yes	yes	yes
Afforestation	yes	yes	yes
Prevention of fires	yes	yes	yes
Care in exploitation	yes	yes	yes

5

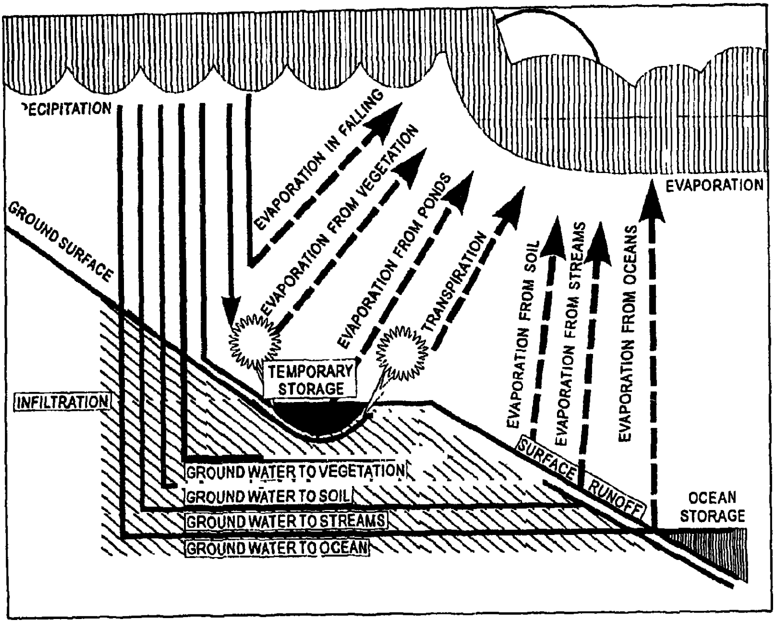
Rainfall and Runoff

Basically, hydrologic cycle is the earth's unending moisture cycle with no beginning or end The moisture cycle rotates between ocean-sky-land-ocean Water from the surface of the ocean is evaporated into the atmosphere The moisture-lader warm air resulting from evaporation rises and cools Cool air condenses on the dust particles in the air, which in turn form small droplets These droplets form either clouds or fog The droplets may remain suspended and be re-evaporated into the air without producing precipitation It may fall as precipitation, due to increased size and weight, in the form of rain, snow or hail. The precipitation may be intercepted before it reaches the ground, especially on leaves, stems and branches In this way 5-15% of annual rainfall is evaporated from intercepted precipitation The precipitation which reaches the soil surface may be absorbed by the soil through infiltration or may not be absorbed by the soil and become surface flow Some water enters in the soil This sub-surface water either increases the soil moisture upto the field capacity or flows through the soil Water held in the soil evaporates or is transpired by vegetation and the water flowing through the soil enters the groundwater reservoir Moisture is returned to the air to form the clouds through evaporation while falling from the surface of vegetation, from the soil surface, from streams, reservoirs, oceans, etc , and transpiration from vegetation And the cycle goes on (Figure 5 1)

Rainfall

The term 'precipitation' signifies all forms of water that is received by earth from the atmosphere and includes rainfall, snowfall, frost, hail, etc In India, the major contribution of water is through the rainfall Thus, unless otherwise stated, 'rainfall' is synonymous with 'precipitation' The magnitude of precipitation varies with space and time. It could easily be fathomed by the observation that in India certain parts of the country experience usually high rainfall causing floods, whereas almost simultaneously, certain other parts of the country do not have any rainfall, causing severe droughts Rainfall generally describes that form of precipitation where the size of water droplets is larger than 0 5 mm The raindrops are rarely above 6 mm size, as they tend to break up into smaller drops during their fall

Figure 5.1 *The hydrologic cycle*



from the clouds. Some rains are highly beneficial, as they supply the needs of vegetation (crop or plants). The damaging rains may come at a rate which is greater than the infiltration capacity of the soil and cause high rates of runoff and erosion Even with moderate rainfall, infiltration is rapid initially and gradually the soil pores are reduced by the pounding action of the raindrops and clogged with the fine material from the muddy water, infiltration reduces and runoff increases Rainfall is termed as light when its intensity is less than 2.5 mm/hr, moderate between 2.5 and 7.5 mm/hr and heavy when the intensity is more than 7.5 mm/hr. Drizzle is a form of rain with numerous droplets of size less than 0.5 mm with an intensity less than 1 mm/hr. Hailstorm is a form of precipitation in the form of irregular pellets or lumps of frozen rain of size greater than 8 mm. In India, snow occurs only in the Himalayan region and is the reason for perennial snowfed rivers

Precipitation may not occur if one or more of the following conditions do not exist

(a) *Moisture in atmosphere* There must be a continuous supply of moisture, at least for some time, into the aircolumn That is, there should be net horizontal inflow of water vapour into the region. Convergence of different oceanic currents, convergence of different air masses, formation of low-pressure zones, etc , may provide such conditions

(b) *Mechanism of cooling of air* At a given temperature, the moist air moves upward and cools down with the resulting condensation of moisture The cooling may also be caused by the incursion of cold air over a warm moist region where the warm moist air is lifted upwards.

(c) *Condensation mechanism* In air without particulate matter, 400% humidity may be required But if some hygroscopic nuclei are present, condensation can take place at a lower moisture content. Usually, large quantities of such matters facilitate condensation at relative humidity less than 100%.

(d) *Mechanism of growth of droplets*: Condensation forms droplets which are very small (10-4 cm radius) They are so light that they remain suspended till the droplets grow big enough to overcome the frictional resistance to falling

(e) *Accretion process*: After the initial formation of cloud droplets by the diffusion process, further growth of cloud droplets requires the presence of some large droplets. Large droplets attain terminal velocity relative to smaller droplets resulting in collusion and growth of large ones at the cost of smaller ones.

Rainfall parameters

Adequate data on rainfall of an area provide the basic information required for land and water management Following are some of the important parameters·

Intensity and duration

Rains of high intensity last for a fairly short time and cover relatively small area Storms covering large areas are usually less intense, but last for a longer time The period during which the rainfall occurs is known as *duration of rainfall* The *intensity* is defined as the rate at which rainfall takes place It is the amount of rainfall occurring per unit time. Duration is expressed in the unit of time and intensity in mm/hr or cm/hr A rainfall seldom occurs at a uniform rate throughout the duration of the storm The rainfall with greatest intensity at the beginning is termed as *advanced storm*, in the middle as *intermediate storm* and at the end *delayed storm* Maximum runoff is usually produced by a delayed storm, as the highest intensity of the rainfall occurs at the time when the rate of infiltration is least Rainfall intensity decides the runoff Thus, more the intensity, more is the damage done to unprotected soils

Rainfall frequency

It denotes the period in years during which a storm of a given duration and intensity can be expected to recur The frequency of occurrence and seasonal distribution of intense rains are extremely important factors affecting runoff and erosion. The frequency can be expressed as percent chance, e g., a 50 years frequency has a 5% chance The damage is more when intense rains occur during the time that a seedbed is prepared, during planting time, or when crop canopies are being established Soil erosion is highly dependent on the timing of intense rains The rainfall factor (R) gives an indication of the frequency of intense rains The cropping pattern or SWC measures should be adopted in such a fashion that the runoff and consequent erosion is protected Frequency has an economic significance in the design of conservation structures SWC structures in integrated watershed development should be designed for the heaviest rainfall recorded during the last 10-25 years (or equivalent to the life period of the structure)

Amount of rainfall

The depth to which rain water would stand on a horizontal surface with conditions of no infiltration, no runoff and no evaporation is known as the *amount of rainfall* Observations for a specified period like days, weeks, months or years may be made. It is expressed in terms of linear units, i.e., in millimetre (mm) or centimetre (cm).

Rainfall measurement

There are considerable variations existing in the annual rainfall among different areas in India. Even in normal monsoon year, Assam may get a rainfall as high as 2500 mm, whereas Rajasthan may get only 100 mm. The average annual rainfall for the entire country is approximately 1200 mm (for district Jhabua, it is around 830 mm). At any given station, there may be varied rainfall This variation can be defined by *coefficient of variation*, which is the ratio of standard deviation of the year-to-year rainfall to the mean amount. The coefficient variation varies between 10% and 60% in different regions of the country. It is highest in dry, arid and low rainfall areas, making them more susceptible to drought Precise and accurate measurement of rainfall is necessary for estimation of runoff and effective planning for integrated watershed development

Rainfall measurement is based on sampling method of estimation. In this method, the raingauges are located at predetermined points in the watershed and average value is arrived at. Usually, the world over, rainfall is measured in millimetre. If rainwater falling on a horizontal and flat projection of earth's surface is, say 1 mm, then it represents a volume of water equal to 10 cubic metre/ha. Thus, a slight discrepancy in recording may lead to faulty estimation of volume of water available from rainfall in watershed areas Raingauges used to determine the rainfall may be non-recording (standard) or recording raingauges. More than 5000 stations have been established in India to record rainfall from raingauges. Most of them are managed by meteorological department, though some are also established by irrigation department or revenue department

Types of raingauges

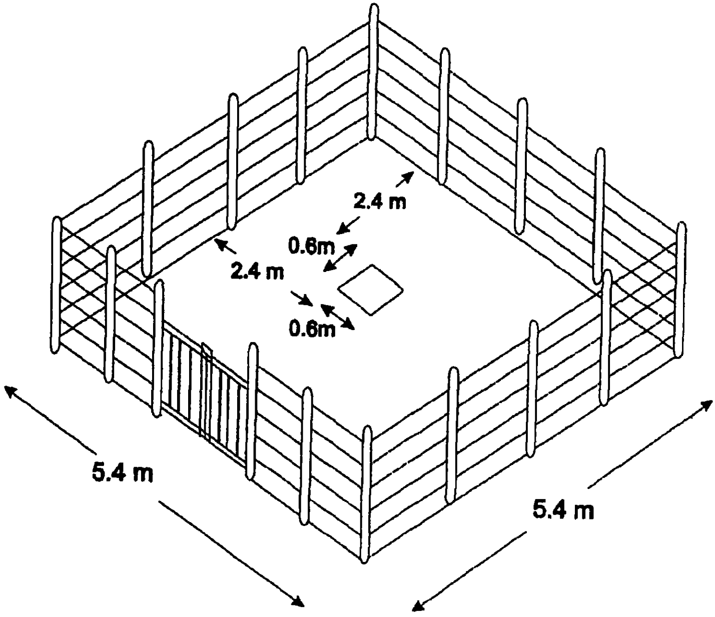
(a) *Non-recording or standard raingauges*. The raingauges give the total rainfall between two consecutive observations In India, observations are recorded at 08 30 hrs (IST) for the preceding 24 hours period. The Indian Meteorological Department (IMD) has recommended the use of Symon's non-recording raingauges for measurement of rainfall The Symon's raingauge instrument is essentially a receiver funnel with 127 mm diameter and 125 mm high circular brass rim and the receiver funnelled into a 175 mm capacity container. The measurement readings are taken from calibrated graduated cylinder with a capacity to measure 25 mm of rainfall Numerous modifications or alternatives of non-recording raingauges are now in vogue (Figure 5.2).

(b) *Recording raingauges*·

(i) *Float or siphon type* This is the most commonly used recording raingauge in India The rainfall is collected by a funnel shaped receiver into a float chamber causing the float to rise With the rise of the float, a pen attached to the float through a lever system records the elevation of the float on a rotating drum When the float reaches a preset maximum level, siphon arrangement empties the float chamber (Figure 5 3)

(ii) *Tipping bucket type*· This raingauge is gaining popularity in India The water collected into the funnel falls into one of a pair of small buckets These buckets are so delicately balanced that when 0 25 mm (or 0 1 mm or 0 2 mm) of rainfall gets collected in one bucket, it tips and brings the other one in position The tipping action is linked with an

Figure 5.2 *Symon's rainguage*



(A) ENCLOSURE FOR RAINGUAGE

electrically driven pen to mark on a rotating drum. The instrument can be digitalised to transmit output signal through telemetry. It has two inbuilt inadequacies. One is that the rainfall which is less than the capacity of the bucket compartment is invariably not recorded. Secondly, any rain falling during tilting of the bucket is 'lost'.

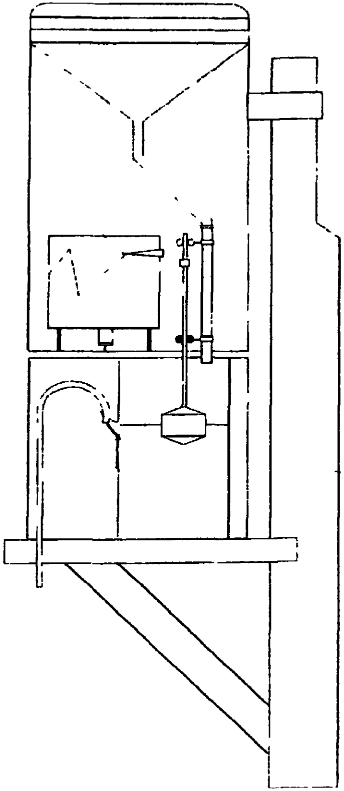
(iii) *Weighing bucket type.* In this raingauge, the collected water from the funnel empties into a bucket mounted on a weighing scale. The catch of water may be checked by weighing it again and measuring it volumetrically This raingauge is not recommended for use.

Measurement through raingauge

For accuracy and consistency, the raingauge should be placed away from elevations (like trees, hillocks, etc.). In undulated terrain, it should not be located near the top of steep ridges or in deep narrow valleys Ideally, the raingauge should be established on an erected masonry concrete foundation (60x60 cm). It should be so located that the rim of the gauge is exactly 30 cm above ground level The base should be firmly secured and the rim should be perfectly levelled. The rainfall observations should be recorded at 08.30 hrs (IST) for 24 hours interval. The funnel opening, container and the measuring glass should be periodically checked for leaks and cleaned. Vegetative growth like weeds, grasses, plants, etc., around the gauge, should be periodically clipped or removed

The recording raingauge should be placed exactly vertical with receiver edge horizontal and 75 cm above ground level Periodically checking and cleaning of all the components of

Figure 5.3 *Syphon type recording gauge*



a = 200cm^2
b = Flot chamber
c = Flot
d = syphon
e = Chart drum
f = stylus
h = Height above ground
(Usually 60 cm)

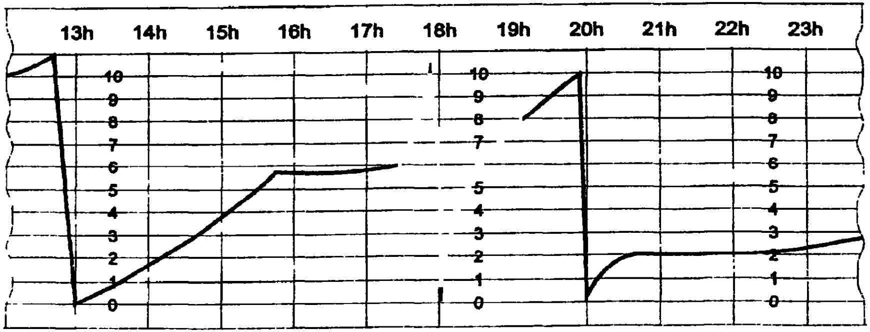
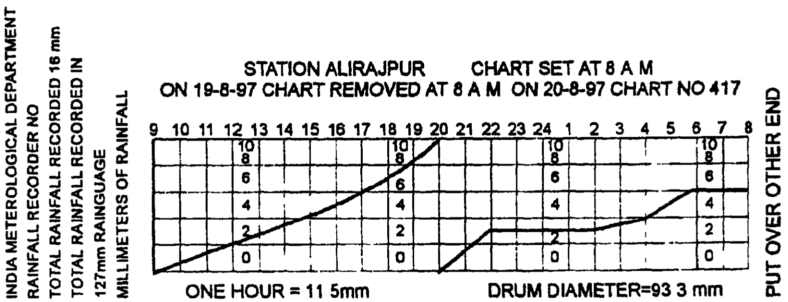


Chart produced by a syphon type recorder the raingauge should be done by trained personnel.

Depending on the pattern of rainfall received, horizontal line (no rainfall), steep slope (intense storm) or mild slope (low intensity rain) are depicted on the recording chart. The information gathered from the standard or recording raingauge is used for calculating various rainfall parameters like calculations of intensities for different durations. Intensity-duration relationships and rainfall intensity-duration-frequency relationships could be easily worked out (Figure 5.4).

Figure 5.4 *A typical raingauge chart*



Estimation of average rainfall over an area

The rainfall over a large area can never be same. So, for estimation of average rainfall in a milli-watershed, a sufficient number of raingauges should be located, spread over the entire area. The readings of raingauges spread in a milli-watershed are analysed to achieve the average depth of the rainfall. This may be undertaken by using any of the following methods.

(a) *Arithmetic mean*: The average rainfall is obtained by dividing the sum of the readings from all the raingauges in the milli-watershed by the number of raingauges This method may not be very accurate as the raingauges may not ideally be distributed all over the area and the rainfall may not vary in a regular fashion For example, if total reading from five raingauge stations (for 24 hours) is 22 mm, then the arithmetic mean of rainfall would be 4.4 mm. More accurate methods have now been evolved.

(b) *Thiessen method*. The location of the raingauges is plotted on a map of the milli-watershed and they are connected by straight lines. Perpendicular bisectors are marked on each of the lines such that each of the raingauge station is enclosed in a certain area. If R1, R2, R3.. are the amounts of rainfall recorded in each of the raingauges, average rainfall (R), over the given area (A), is given by the formula as under:

$$R = \frac{R1A1 + R2A2 + R3A3 + \dots}{A1 + A2 + A3 \dots}$$

(c) *Isohyetal method*: Raingauge stations are plotted and located on the map and the amounts of rainfall at each of the station are gathered. Isohyetals (lines of equal rainfall) are drawn by interpolation on the map. The area between the successive isohyetals is determined, for which plainmeter can be used. If R1, R2, R3... are the amounts of rainfall recorded in each of the raingauge and A1, A2, A3 ... are the areas of the irregular figures in between isohyetals, then the average rainfall (R) could be expressed by the formula given below.

$$R = \frac{R1A1 + R2A2 + R3A3 + \dots}{A1 + A2 + A3 \dots}$$

Factors affecting runoff

Surface runoff is defined as the precipitation that flows over the ground surface and through channels to larger streams. Runoff is a part of the rainfall that flows towards rivers, oceans, etc., as surface or sub-surface flow Generally, the surface flow is called *runoff*. Before surface runoff can occur, precipitation must be in excess of that required for evaporation, interception, infiltration, surface detention and storage. After the rainfall, a part of the precipitation is intercepted by vegetation and evaporates to the atmosphere. A portion of it is stored in depressions, known as depression storage, which gradually infiltrates into the ground and partly evaporates Excess water starts infiltrating through the entire surface area and if the rainfall rate is more than the infiltration rate at that time, then the surface flow starts This surface runoff joins streams, rivers, reservoirs, oceans, etc The water that infiltrates in the soil but does not percolate down to join the groundwater table may flow laterally to join the stream below (sub-surface flow). The portion of the water percolating into the groundwater table may flow to join the stream downward (groundwater flow). Thus, sub-surface flow and groundwater flow may add to the runoff The following factors affect runoff

Quantities and rates of runoff

In a hypothetical watershed area with an impervious surface and no losses, the maximum rate of runoff would be directly proportional to the rate of rainfall Rainfall, which is evenly dispersed throughout the year, has a different impact as compared to sudden sharp showers or seasonal rainfall Some of the rain is intercepted by vegetation, some infiltrates into the soil, some starts moving over the surface but is trapped in depressions, and some is lost by evaporation The structures for SWC and water harvesting should be constructed after giving due consideration to the quantity and rate of runoff.

Intensity and duration of rainfall

With the increase in intensity, runoff increases at a higher rate as the infiltration capacity of the soil remains almost constant As the duration increases, the runoff rate increases due to decreased infiltration rate In the advanced stages of the monsoon, longer duration of rainfall may bring the watertable close to the surface and produce very high runoff to cause floods. The areal distribution of the rainfall affects the runoff in watershed. A high, intense rainfall occurring near the outlet contributes more to the runoff compared to the storm occurring on the upper reaches. Similarly, when rainfall at a point of the watershed is much higher than the average rainfall, runoff will be higher than for a uniformly distributed rainfall Temporal distribution also affects the runoff.

Time of concentration

It is defined as the longest time taken for water to travel by overland surface flow from any point in the catchment to the outlet. The larger the catchment, the longer is the time of the concentration. Undulated topography with steep slopes will cause shorter time of concentration and faster runoff. The ratio of the length of the watershed along the mainstream (L) to the average width (W) of a watershed is termed as its *shape factor* (L/W) A high shape-factor results in longer time of concentration and thus causes a reduction of the peak discharge rate. Long and narrow watersheds are likely to have longer time of concentration resulting in lower runoff rates than more square-shaped watersheds of the same size. In short, the longer the time taken by the water to leave the watershed, the greater is the opportunity of the water to soak into the soil and lesser is the runoff.

Land slope

The speed and extent of runoff depends on the slope of the land. The greater the slope, the greater the velocity of flow of the runoff water Velocity varies as a square root of the vertical drop So, if the land slope increases four times, the velocity of water flowing on the slope is doubled The energy and consequent erosive capacity is increased four times Thus, the erosive capacity of runoff varies in direct proportion with the slope of a land on which runoff occurs Also, the quantity of material that can be carried is increased about thirty two times and the size of the particles that can be transported by the runoff is increased by sixty four times. The long slopes are divided through various SWC measures into a series of short units, which decrease the velocity and the resulting runoff.

Drainage density and pattern

The drainage density of the watershed affects runoff. High drainage density watersheds drain runoff water rapidly. The drainage density of a watershed is the total length of all streams (in km) divided by catchment area (in km^2) The drainage pattern of the watershed refers to the design and distribution of the stream courses and their tributaries. Slope, structure, geology, distribution of rocks control the drainage pattern. Runoff is relatively less in areas where trellis, rectangular and annual drainage patterns are observed. Moderate to severe runoff is usually seen in watersheds with radial drainage pattern In areas where a dendritic drainage pattern is observed, the runoff is severe to very severe

Hydrologic conditions of soil

The soil and its hydrologic condition, in most cases, affects the volume of runoff, probably more than any other single factor The hydrologic condition of the soil is determined by its moisture content at the time of the storm, its humus organic content and temperature Crop residues and residual root system from grasses and plants produce a good hydrologic condition

Vegetative cover

Vegetation affects runoff in numerous ways. Grass cover is evaluated on basal area of the grass, whereas trees and plants are evaluated on the basis of canopy cover. The foliage and litter from the vegetation maintain the soils' infiltration potential by preventing the direct impact of the raindrops on the soil surface. Some part of the rainfall is intercepted by the leaves or branches of the vegetation which allow such trapped moisture to evaporate Some of the intercepted moisture takes such a long time draining from the plant down to the soil that it is withheld from the initial period of runoff. Transpiration of soil moisture from previous rainfall leaves a void in the soil, which has to be filled Most importantly, the vegetation forms numerous barriers along the path of the water flowing over the surface of the land, which increases the time of concentration and reduces runoff.

Land management practices

They reduce sheet erosion and so maintain open structure of the soil surface. The runoff is reduced by such practices but the situation might change with heavy rainfall Contouring and terracing, for example, reduce sheet erosion and increase the amount of rainfall withheld from runoff. Similarly, gradient terraces increase the distance water must travel, which in turn increases the time of concentration and reduces peak rate of discharge Practices such as contour farming and strip-cropping, which retard the flow of water, are effective in reducing runoff by increasing both the amount of infiltration and the time of concentration.

Estimating runoff

Runoff computation is essential for taking up many of the soil conservation measures like erosion control structures and channels to carry maximum runoff For designing spillways and outlets or waterways, estimates of peak runoff rates are required. On the other hand, assessment of the storage in earthen dams, tanks, ponds, etc , requires the estimation of total runoff volume or water yield A very approximate estimation of the runoff could be undertaken by the PIA with the help of the hydrograph of the watershed A *hydrograph* is basically a drawing which represents the rate of water flow at a certain point along a waterway Rise and fall of water levels in stream against time is plotted to give hydrograph of the flow By superimposing the rate of precipitation on the watershed hydrograph, PIA can determine the reaction of the watershed, as far as runoff is concerned, to various types of storms. Following methods are used for estimating peak runoff (Figure 5.5)

(The estimation of peak runoff is based on the presumption that rainfall occurs at uniform intensity for a duration atleast equal to the time of concentration of the watershed and rainfall occurs at uniform intensity over the entire watershed)

Rational method It is the most widely used method for the estimation of peak rate of discharge from small watersheds It is expressed by the equation

$$Q = \frac{CIA}{360}$$

where

Q= Peak rate of runoff (in cum/sec) for the given frequency of rainfall

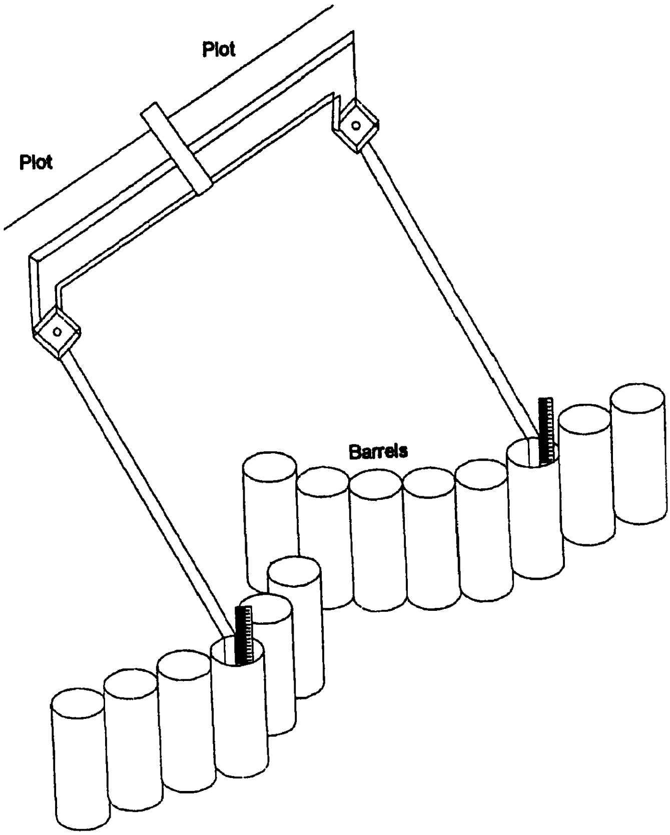
C=Rational runoff coefficient having values ranging from zero to one depending upon watershed conditions

I=Intensity (in mm/hour) for design frequency and for duration equal to time of concentration

A=Area of watershed (in hectares).

Rational runoff coefficient C is defined as the ratio of the peak runoff rate to the rainfall intensity. Values of C for different slopes, land use and soil types are given in Table 5.1. The factor I is the rainfall intensity for a given duration and return period and is expressed in mm/hour. Once the duration of the storm is known, I can be estimated by

Figure 5.5 *Runoff-water collection apparatus*



dividing the value of amount of rainfall by the duration (in hours). The duration of the storm is set equal to the time of concentration of the watershed. Values for time of concentration can be estimated by using standard graphs.

Table 5.1 *Values of C used in rational method*

Vegetative cover and slope	*Soil texture*		
	Sandy loam	*Clay and silt loam*	*Stiff clay*
Cultivated land			
0-5%	0.30	0.50	0.60
5-10%	0.40	0.60	0.70
10-30%	0.52	0.72	0.82
Pasture land			
0-5%	0.10	0.30	0.40
5-10%	0.16	0.36	0.55
10-30%	0.22	0.42	0.60
Forest land			
0-5%	0.10	0.30	0.50
5-10%	0.25	0.35	0.50
10-30%	0.30	0.50	0.60

The rational method is normally accurate for watersheds which are less than 1300 ha The area under various land use and soils can be determined If the watershed comprises of more than one land use or soil types, the average value of C is computed as

$$C = \frac{A1C1 = A2C2 + . . An\ Cn}{A}$$

Tc can be calculated from the following empirical formula

Tc = {L/3}/0.5 (Ven Te Chow)

where.

Tc = Time of concentration (in minutes)

L = Maximum length of flow (in metres)

Convert the one hour intensity for design frequency for duration equal to time of concentration by using the formula

$$I = \frac{KT/a}{(t + b)/n}$$

where

I = Intensity (cm/hr)

T = Return period (years)

t = Storm duration (hours)

The values of K,a,b.n can be derived from standard tables.

The peak rate of rainfall can be computed by using the rational formula

The other methods of estimating runoff are

(a) Cooks method
(b) Hydrologic soil cover complex number method
(c) Table method

Details about the formulae and procedure for computation can be obtained from any standard SWC textbook It has been observed in Jhabua that peak rate of runoff of a watershed can be easily and accurately computed by rational method.

6

Topographic Surveying

Surveying or survey levelling is practised to measure distances (horizontal distances), to determine the differences in elevation (vertical intervals), to set out contour lines, etc Complex levelling and surveying equipments and techniques are available, but these could only be handled by experts The following mentioned equipments can be assembled at home and can be used by the farmers or villagers, if proper capacity-building has been ensured In a watershed area, it is necessary to measure distances, the area of the fields and watersheds, the volume of earth in excavation and embankments, etc The methods and equipments required in measuring distances depend on the accuracy required in the work for which the measurements are made, equipment available, size of the object or area to be measured and the condition of the terrain Generally, accuracy is achieved by calibrating the measuring device against a known standard, and precision is related to the quality of the instrument and the care taken in reading it Thus, accuracy is obtained by using properly calibrated instrument and precision is obtained by carefully using that equipment

It is necessary to record measurements made in the field The data must be clearly and accurately recorded in a standard format All the data arrived at in the field should be recorded in the field, and preferably in the fieldbook itself The hard lead pencil or a dotpen is recommended for putting up data on the fieldbook As far as possible, standard formats should be evolved by the PIA, so that others can also use the fieldbook in future with reasonable ease Ideally, LHS page of the notebook should be used for recording numerical data and RHS page should be used (in a rectangular grid paper) for pictorially/graphically drawing the findings in a form of sketch

Equipments for measurement of distance

Numerous methods and equipments are available to measure the distances in watershed areas Some of them are described below

Chains

A chain is made up of interlinked steel or galvanised segments, of 20 cm each There are usually 100 such segments or links, making the total length of the chain close to 20 m Special joints or tally marks are attached on the chain at every 5 m distance. Similar chains called *jaribs* are commonly used by *patwari* (village revenue officer) for measuring length, breadth, etc , of the agricultural plot. The measurement of distances using chains are not very accurate, though the method is less time-consuming. The measurements will always have false interpretations as measurement below 20 cm can never be accurately and precisely recorded The chains require frequent adjustments and are susceptible to wear and tear at many link connections Steel tape has almost made chain redundant as a measuring device

Measuring tapes

Measuring tapes with 1, 2, 5, 7 5, 10, 15, 25, 30 and 50 m lengths are available for measurements in watershed areas Mostly 30 m tape is used Linen or cloth tape is not frequently used due to its inaccuracy. It is made of varnished strip of woven linen 12-16 mm wide with a brass handle at zero end (the length of the handle is included in the length of the tape) The tape is hooked to a spindle and is wound in a leather case Metallic tape is better than linen tape and is made of good quality linen with fine brass or copper wire reinforcement These tapes are not recommended for measuring precise distances The tape is occasionally coated with a suitable primer and enamel to make it durable and water-resistant Steel tape is made up of steel ribbon of stainless steel and is considered very accurate The tapes are marked at every 5 mm, cm and m The first 10 cm is also graduated upto 1 mm The case of the tape is made of corrosion-resistant metal Iron tape is made of an alloy of 36% nickel and 64% steel It has a very low coefficient of thermal expansion It is a very accurate and precise mea~urement device A proper type of tape should be selected for measuring distances and areas. These tapes are broken easily if not properly handled They should not be jerked needlessly. They should not be stepped over or run over by vehicles, etc., and should not be bent around sharp corners The user should avoid pulling it when there is a kink or loop in the tape. The deformations caused in handling should be immediately corrected mechanically The tape should not be dragged on rough surface, as it would result into abrasions on the marking side The tape should be cleaned and dried after a day's use They may be wiped by oil-soaked soft linen

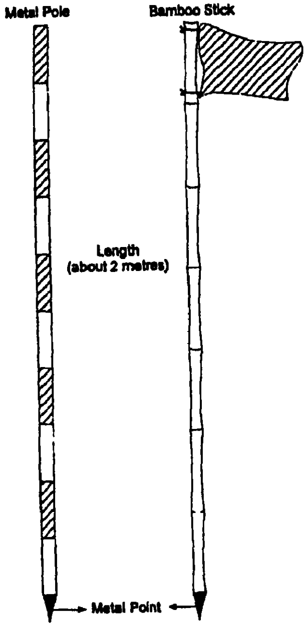
Measuring rod

Measuring rod is a straight *lath* with a length varying from 3 m to 5 m These rods are also marked with mm, cm and m The usefulness of rod is doubtful on undulating terrain

Other equipments

(i) *Arrow* The arrow is made of metallic wires or thin rods The arrow is in the shape of letter 'p' with a pointed end (for fixing on the ground) and a loop at the other end (for holding it) The arrows are used as pegs, to mark the end of the chain, tape or rod They are usually used when certain points on the field require permanent marking Pegs are made of wood, and metal Even straight tree branches properly sharpened can also be used The size of the peg/arrow ranges from 40 to 75 cm They are driven verti-

Figure 6.1 *Ranging poles*



cally into the ground and the top is left visible (Figure 6.1).

(ii) *Ranging rods/poles*: They are used to mark stations,which must be seen from long distances. Ranging poles are also used to mark areas and to set out straight lines on the field. They may be made in home or village from strong and straight bamboos or tree branches. It should never be curved. They may be made of straight and round, light and strong bamboos, seasoned wood or steel rods The lower end is provided with an angle or pointing to facilitate fixing in the ground. The rod should be very straight and 2-3 m long. To enhance visibility during measurement, they may be painted with alternate black-white or red-white columns Flags may be fastened at the top (Figure 6.2).

(iii) *Plumb bob* This is a very common device used in India by carpenters and masonry workers to check if object is vertical or not. It consists of a piece of heavy metal, (usually brass) pointing downwards and is attached with a string or cord. When the plumb bob is hanging free, without swinging or curling oscillations, the cord is vertical It is also used for accurate centring of compass or level over station mark (Figure 6.3)

(iv) *Carpenter level* It is an instrument which is used to check whether objects are horizontal or vertical A carpenter level consists of one or more curved glass tubes (called level tubes). The tube is seated and partially filled with liquid (oil, water or paraffin) and remaining space is air, which is visible as a bubble. There are horizontal and vertical levels on every instrument. Only when the carpenter level is exactly horizontal (or vertical), the air bubble will be exactly in between two marks (Figures 6 4 and 6 5)

Figure 6.2 *Pegs*

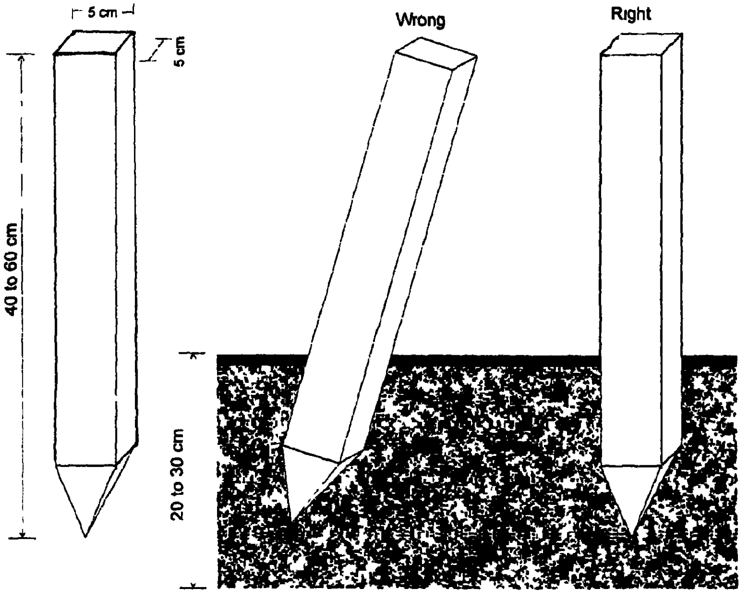


Figure 6.3 *Plumb bob*

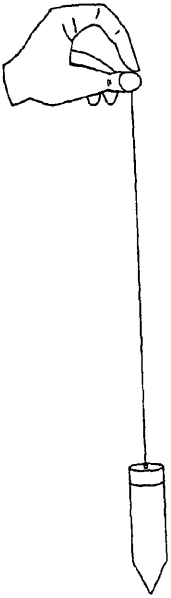


Figure 6.4 *A carpenter's level*

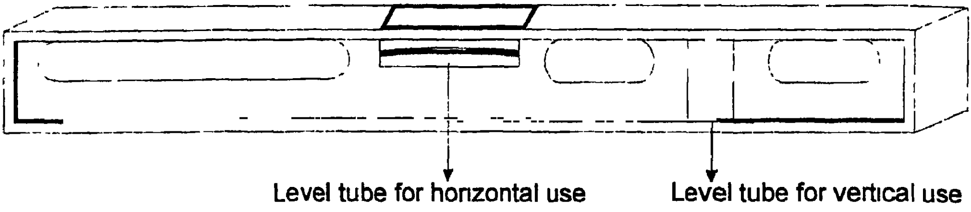
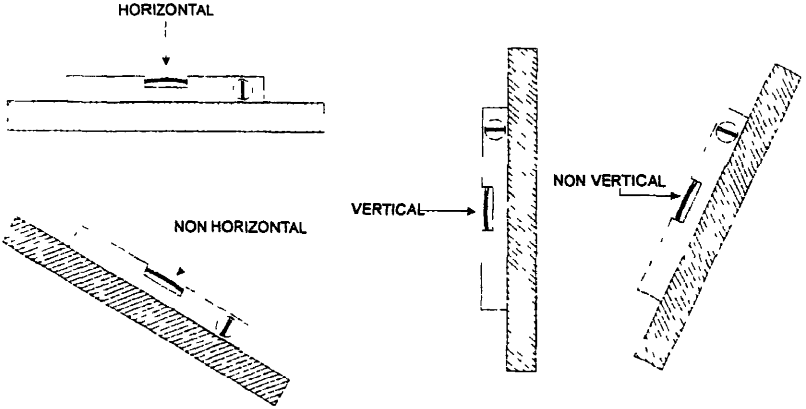


Figure 6.5 *Using the carpenter's level*



Setting out straight lines and measurement of distances

In any watershed, measurement of distances and areas depends upon the accuracy in setting straight lines The initial step requires correct placement of ranging poles. The pole should be held loosely between thumb and index finger, with the lower end of the pole kept 10 cm above the ground The assistant releases the pole, when the observer indicates that the ranging pole is in the right position. The pole is then set into the ground. It should be checked if the ranging pole is vertical, by the means of plumb bob or a carpenter level

(a) *When the distance is short*: Ranging poles could be easily laid, as the distant point is close and visible from the observer's point. The observer stands around 1 m behind pole A On closing one eye and readjusting the location, when the observer finds pole A and B overlapping, the ranging poles are in straight lines Other poles, say C, D, etc may be placed between A and B and are said to be in straight line when observer standing 1 m behind pole A, sees pole A only when the other poles are hidden behind pole A.

(b) *When the distance is long*· In such circumstances, observer standing at pole A cannot see pole B clearly. It is advisable to attach a flag on pole B to make it more visible Pole C is approximately set in line with A and B at about one-third of the distance between A and B, close to pole A The observer moves to pole C and pole D is set in line with C and B. The observer moves to pole D and pole C is reset in line with D and A Intermediate poles E, F, etc., could now easily be set in line with A-C, C-D, D-B.

(c) *Ranging across a hill*. Due to hill, hillock or obstruction pole B may not be visible from pole A Setting out straight line in such a situation requires two observers and two assistants. The method involves selection of two intermediate stations C and D, such that ranging poles at B and D are visible from C and ranging poles at A and C are visible from D. The poles at C and D are located in such a fashion that CDB is in nearly a straight line The observer at pole C looks towards B and directs the assistant at D to fix it in such a manner that CDB are in straight line Observer on pole D looks towards the ranging pole at A and directs the assistant at C to fix the ranging pole at a location that ACD is in the straight line. When observer at C finds CDB in straight line simultaneously with observer at D finding ACD in straight line, then ACDB will lie in one straight line

Following the ranging of poles in straight line, the measurement could be taken up with the help of chain or tape. The assistant holding the rear end of chain or tape is called the *follower* and the one holding the forward end is called the *leader* The follower carries the rear end, directs the leader to move in a straight line with the ranging pole at the forward station and picks up arrows/pegs fixed by the leader On the other hand, the leader drags the chain/tape, follows the instruction of the observer or the follower and inserts arrows/pegs at the end of a chain length or tape With the help of chain/tape and arrows/pegs the distances on relatively plain surface could easily be calculated The distance required to be measured in surveying is the horizontal distance If the land slope is less than 3 degrees, for all practical purposes it is generally considered as horizontal If the land slope is more than 3 degrees, then one of the following methods should be considered

(a) *Direct method/stepping method* This method consists of measuring the sloping line in short horizontal lengths in a stepping fashion Let AB be the sloping line, then its horizontal length can be measured The total horizontal distance measured is Aa + a1b + b1c + c1D

(b) *Indirect method* The angle of the slope is measured by dinometer abney level When the slope is varying, then at each change of slope the slope angles Q1, Q2, Q3, etc and corresponding lengths L1,L2,L3, etc , are measured The horizontal distance is L1 cos Q1 +L2 Cos Q2 + L3 Cos Q3, etc For a uniformly sloping length, the horizontal distance can be computed by measuring the sloping distance and the vertical distance If the sloping distance AB equals L and the vertical distance AC equals h, then the horizontal distance

$$BC = \sqrt{(l^2 - h^2)}$$

A fieldbook is commonly used for noting the readings when the survey is carried out. The fieldbook is 22 5 cm x 12 5 cm and opens lengthwise. Two red lines are drawn in the middle of each page Chainage lengths or measurements of tapes are written in between the two red lines and the space on either side is used for writing the offset lengths, drawing rough sketches of figures, etc The noting is generally initiated from the last page of the book The recording goes on continuously on preceding pages with the observer moving in the direction of chain line. Initial and final readings are marked with a symbol A and capital letters B, C, D, etc., are used to mark various stations. The surveyor should face the direction of chaining and offsets in the field New chain lines should be started from a new page

It is necessary to plot the fieldbook readings properly on drawing sheet using a suitable scale The base line should be plotted accurately and in such a manner that other readings can be easily accommodated It is recommended to mark the north side towards the top of the map. The intermediate stations should be marked on the baseline and the angles/side distances should be noted. The title of the survey, name of the surveyor, location and date should be written at the right hand bottom corner along with the scale used.

Setting out right angles

The right angle may be laid by using chain/ tape or by using different instruments For laying right angle by using chain or tape, the following methods may be used

(a) *Three-four-five method.* It is based on the principle that if the three sides of a triangle are in 3:4·5 proportion, it is a right angled triangle For example, let it be required to lay out a right angle at point A on a chain/top line From A, a distance AB, equal to multiple of 4 (say 4 m) is measured on the chain/tape line Taking A as the centre, an arc of 3 m and with B as the centre, an arc of 5 m are drawn These two arcs meet at C A is joined, which is the requisite perpendicular on AB at point A.

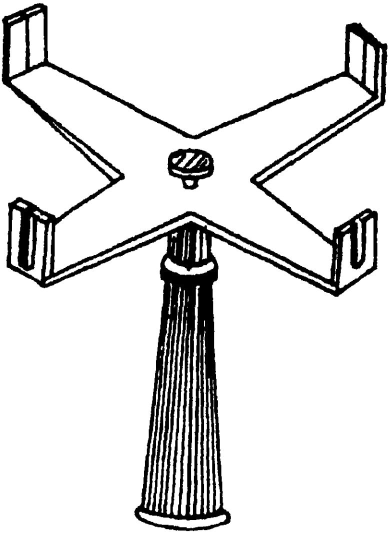
(b) *Chord method* To draw a perpendicular on point A off the line, equal distances AB and AC are measured and chords of equal distances AB are measured and chords of equal radii are drawn from point B and C to meet at D AD becomes the required perpendicular To draw a perpendicular from a point A on the line, chords of equal radii are drawn to meet the chain line at B and C. The mid-point of BC is found out as D AD becomes the required perpendicular

(c) *Semi-circle methods* To draw a perpendicular on point A from line, any point B is selected outside the chain line and with B as the centre and BA as the radius, a semi-circle is drawn which cuts the chain line at C. CB is joined and extended to meet the semi-circle at D AD becomes the required perpendicular

Various instruments may be used for setting out right angles Usually, optical square, cross staff, prism square and offset rod are used, the optical square being most commonly used

(a) *Cross-staff* It consists of a head and a leg The head consists of four metal arms at 90 degree each with vertical slits The arm of the head is fixed in such a fashion that the centre of one pair of arms form a straight line and make a right angle with the other pair of arms. The object is sighted through one pair of vertical slit. The leg of the cross staff is around 1 to 1.5 m in length and 2.5 cm in diameter. When the chain or ranging poles are seen from a pair of vertical slits, the other pair of slits depict right angle in the line of sight (Figure 6.6).

Figure 6.6 *Cross-staff*



(b) *Optical square*: It is more accurate and precise than the cross-staff. Generally, it is used to locate objects situated at larger distances It is a small, portable and handy instrument and works on the principle of reflection. It is a round brass box about 5 cm in diameter and 1.25 cm in height A holding rod is attached to it. It consists of horizontal mirror (H) and index mirror (I) placed at an angle of 45 degree to each other. Right angle can be assessed by viewing through a slit/opening Reflection of the object on H and I provides correct angle of the object.

(c) *Offset rods*: They are also used to locate the positions of different objects with respect to chain line This is done by locating lateral measurements with respect to the chain line. Perpendicular offset measure right angles and oblique offsets can measure other angles as well.

Measurement of areas

Sometimes, it is essential to measure the area of a plot in watershed area It is often required to compute the area of an agricultural farm, command area, submergence area, silvipasture plot, etc. Three general methods used commonly are as under·

(a) *Triangulation survey*: It forms the basis of trigonometrical or geometrical surveys This method essentially refers to surveying in which one line is measured with a chain and all the three angles are measured correctly The whole area (generally a closed polygon) is divided into equilateral triangles. The remaining area is computed by trigonometry This method is suitable for small plane areas without obstructions
(b) *Traverse survey* This is recommended for areas with obstructions like vegetation, rocks, etc It consists of a framework of connected lines whose lengths and directions are known. The distances and angles are accurately measured When the end point of a survey coincides with the starting point, it is called closed traverse Otherwise it is open traverse Areas of plots (wasteland, forest), lakes, etc., can be fathomed by close traverse Open traverse is required for surveying narrow strips of land, e g , road, railway, river, canal, etc.
(c) *Grid survey* It consists of a series of measured parallel and perpendicular reference lines laid out at equal distances to form adjoining tiers of equal squares

The survey plan should be arrived at before arriving at the field. List of data needed, best method of obtaining the data, degree of accuracy list of people needed for performing the task, list of needed equipments and time schedule should be finalised Surveying measurements are not always exact, faulty surveying techniques may cause problems So, surveyors should practice for a long period before coming down to execution Limitations and imperfections in the instrument due to manufacturing defects or improper adjustments may lead to error. Lack of attention or carelessness can cause faults

Surveying should always be performed from whole to part and not *vice versa* All the stations established should be intervisible. A long line (baseline) should run through the centre and whole length of the area On this line, the framework of triangles and lines should be marked As far as possible, the number of survey lines should be minimized Long offsets should be avoided. The surveying line (baseline) should be so positioned that obstacles in ranging or chaining could be avoided They should be placed on level ground as far as possible Mistakes in measurement should be corrected with the help of check line or proofline Subsidiary or tie line should be used to measure distant features

The area of the plot is calculated through instrumental or graphical method. Planimeter is the instrument used for computing area from the plotted plan In the graphical method, the area is calculated by dividing the whole area into triangles, squares or rectangles The area of a standard triangle, square or rectangle is calculated The multiplication of such calculated area with the number of triangle, square or rectangle gives the total area Preferably, computation of area should be undertaken from field notes Following formulae are in vogue
(a) *Trapezoidal rule* The sum of the first and the last ordinates plus twice the sum of the intermediate ordinates multiplied by half the common distance between the ordinates gives the required area
(b) *Parabolic rule* To the sum of the first and last ordinates is added twice the sum of the remaining old ordinates and four times the sum of all the even ordinates This total sum multiplied by one-third the common distance between the ordinates gives the required area
(c) *Mid-ordinate rule* The whole area is divided into number of divisions, the mid-ordinates are measured for each division

(d) *Average ordinate rule*· The average of the ordinates at each point of division multiplied by the length of the base line gives the required area

Setting out contour lines and slopes

Undulated terrain, in watershed area, requires setting out contour lines and slopes accurately. Following equipments can be used for such purpose·

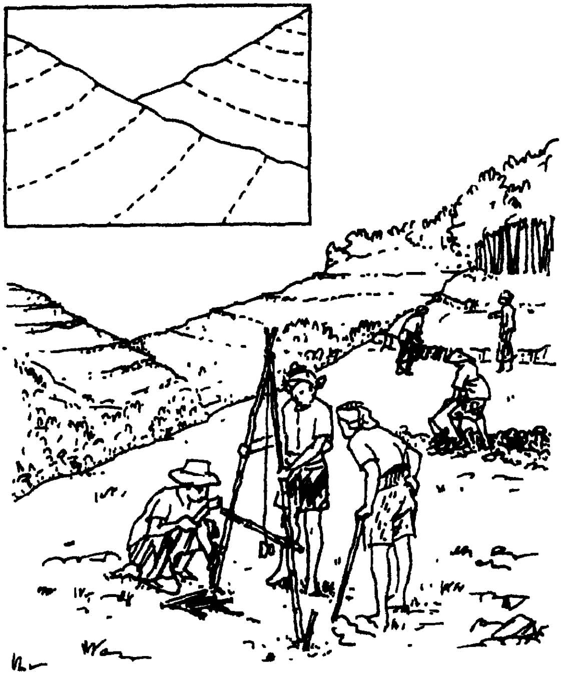
Boning rods = for horizontal lines and slopes,
N/A frame level = for slopes and contour lines, and
Flexible tube water level = for contour lines and differences in elevation.

(a) *Boning rods*· Boning rods are T-shaped equipments, usually made of wood Their height is 1 m and the upper surface of the T has a cross-section of 50 cm x 10 cm. Generally, 4 or 5 boning rods are required To set out horizontal lines or lines with a constant slope, the height/elevation of starting and end points on the line must be known On the starting and end point, bench mark boning rods should be placed along with two or three intermediate boning rods between them on the straightline. The observer looks from just the top of bench mark at the starting point. Other intermediate boning rods top's should be brought in line by excavating or elevating them. By the same procedure the slope can be calculated.

(b) *N-frame level/A-frame level* These instruments are most commonly used in watershed areas for setting out contour lines and slopes. They resemble figure N or A They consist of a wooden frame (main *lath*, 2 legs and 2 cross poles) On the main horizontal *lath*, a carpenter level is firmly fixed with metal strips The A-frame should be tested by checking the carpenter level The frame is placed on plain surface (with points at same elevation, like floor or table) The bubble in the carpenter level should be exactly in between the marks If not so, the carpenter level must be adjusted by putting a spacer under one end of the level. To set out contour lines, one leg of the instrument is placed at the starting point by turning the frame around this leg, a position of the frame is found such that the second leg is on the ground and the bubble of the carpenter level is exactly in between the marks Both points belong to the same contour line The procedure is repeated until the end of the plot is reached The pegs on each point, when joined form a complete contour line Minor adjustments by moving some pegs is necessary to find a smooth line. Second and subsequent contour lines should then be carried out similarly The A-frame can be used to set out lines with uniform slope The A-frame may be provided with plumb bob instead of carpenter level (Figure 6 7)

(c) *Flexible tube water level* It consists of two staffs with a length of about 2 m and a transparent flexible tube about 15 m long The end of the tube are firmly fixed to the staffs The tube is filled with muddy or coloured water, so that the water level is about 1 m high, and each of the tube ends are fixed to the staffs Air bubbles, if any, should be removed Wherever the two staffs are set, the free water surface in the tube ends have the same level These should be marked on the tube One staff is put on the starting point and an assistant carries the second staff (within 10 m of the first one) and searches for a slope where the water level in the tube touches the marked level A peg may be fixed and the procedure is repeated further to find subsequent points of the contour line Marking of line passing through these pegs earmark a contour line Second and subsequent contour lines are similarly marked Care should be taken to avoid

Figure 6.7 *Marking contours by using A-frame*

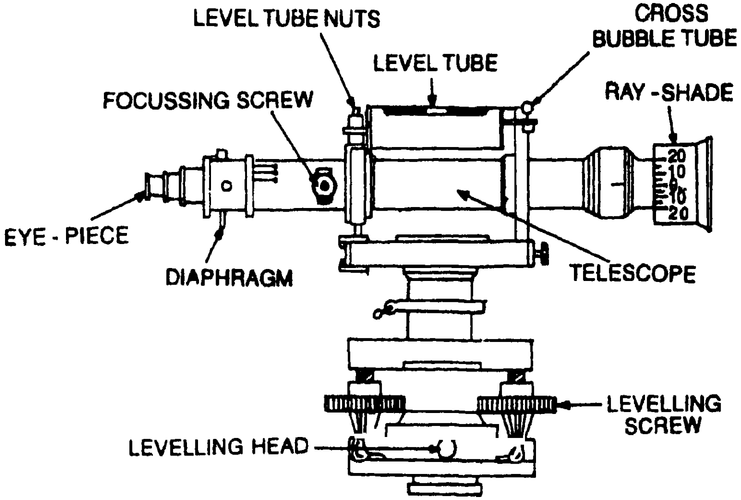


spilling of water whenever and wherever the staffs are moved. Difference in water levels at points on different elevations depict the change in elevation The difference of water level in both staffs is the difference in elevation. If two points are far apart then the process is repeated and differences in summations of readings on each staff give the difference in elevation

Levels and levelling

The level is used to determine the vertical distance or difference in elevation between points. There are numerous types of levels. Sturdy, convenient and adjustable instrument-*dumpy level* is by far the most commonly used. Hand level, abney level and wye level are other types of levelling equipments The dumpy level consists of a frame over which telescope is fixed rigidly The telescope cannot be easily removed from the frame and cannot be moved or rotated about the longitudinal axis. The telescopes are either internal focussing type or external focussing type. The diaphragm consists of cross hairs. One hair is placed vertically which indicates the vertical line and allows the sight of the ranging rod vertically There are three sets of horizontal hairs. The middle one gives the line of sight and the other two are used for distance measurement, when sighted through the top and bottom wires, different staff readings are obtained The difference multiplied by a constant factor gives the distance of the station from the location of the instrument When sighted through the eye piece, continuation of the vertical line meets the levelling staff at a point which denotes the staff reading A magnetic compass is provided below the telescope. The compass enables the observer to read the bearings of the lines along with level reading. Bubble tube(s) are provided for levelling the instrument along with 3 or 4 screws to make required adjustments (Figure 6.8).

Figure 6.8 *Dumpy level*



The dumpy level should be adjusted before using it for taking measurements The tripod of the instrument should be firmly fixed in the ground at a fair level The telescope should be turned and placed over two opposite levelling screws, which should be turned in such a fashion that the bubble lies at the centre of the tube After that, the telescope should be turned by about 90 degree so that it stands over the third screw The third screw should be rotated again to bring the bubble again to the centre The telescope should be turned back to initial position and minor adjustments of the screw should be performed to bring back the bubble to the centre The eye piece should be focussed to have a clear vision of the cross hairs To focus the objective, the telescope should be directed towards the object and the objective is focussed properly, the image and the cross hairs should be in the same plane Whenever, any levelling is to be carried out, the first reading is taken on a point of known elevation (back-sight reading) Another reading is taken on a firm object whose elevation is to be determined (fore-sight reading) Between them many more readings called intermediate sights are taken Various methods exist to determine the reduced level (RL)

If the two points are so close that they can be seen from a single set up, then the level is set up from where both stations are visible It is advisable to locate the instrument at equal distance from both the stations, though not necessarily in the same line Staff readings are taken on both the stations The difference in reading gives the elevation difference between the points. If the two points are far apart, then the levels can be obtained by fixing one or more intermediate points In such cases, it is recommended to repeat the process from last point back to starting point as a check Profile levelling may be required for earmarking contours for bunds, trenches etc The operation starts from a bench mark. Levels are then taken every 10, 20, 30 m. Apart from these stations, the level readings must be taken at all points where there are abrupt changes of slopes All the stations are fixed with pegs/arrows/ranging poles and these should be marked with line This line is a contour line The line should be cross-checked before finalizing it.

Dumpy level instrument is a technical equipment and requires scientific and skillful handling These instruments have limited use in a watershed where the emphasis is on community-based intervention. In specific circumstances the instrument may have a limited use, especially when a technical assistant is available in MDT Usually, simple and user-friendly instruments should be used for measurement of distances, angles, areas and contours The instrument may not be precise but its easy handling ensures remarkable accuracy The use of A-frame in Jhabua has been found functionally sufficient for setting out contour lines and slopes Chain, measuring tapes, arrows/pegs, ranging rods, plumb bob, carpenter level, optical square and A-frame serves the purpose of WDC or PIA for all sorts of measurements in watershed

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7

Participatory Rural Appraisal in Watershed Programme

It is an accepted fact that the traditional approach towards rural realities has been lacking in several aspects Misinterpretation, misjudgement and mispresentation of situation have resulted in wrong perception and knowledge about the field conditions

Various participatory learning and action techniques were adopted to bypass such problems *Rapid rural appraisal* and *participatory rural appraisal* are growing families of methods and approaches to enable local people to express, emphasise, share and examine their knowledge of life and conditions to plan and to act Rapid rural appraisals (RRAs) were evolved to be cost-effective and quick techniques Indigenous technical knowledge (ITK) was observed in the villages and a large number of professionals realised and recognised the obvious fact that rural people were knowledgeable on subjects related and important to their lives ITK became the source of information and to tap that cost-effective and time-effective RRA approaches were realised RRAs grew over and above the structured and unstructured questionnaire format and helped professionals to restrict the type, quality and quantum of information It also created situations and circumstances for the outsiders to come physically in close contact with the rural people which created amenable free flow of information RRAs made formal surveys a part of history The basic fundamental merits of RRAs were (i) it made flexible, exploratory, interactive and innovative progressive learning possible; (ii) it created two-way communication situation where free flow of ITK, attitudes, informations, etc, became possible, (iii) it also created a new perspective to credibility, validity and repeatability of the information, (iv) it allowed for information to be collected using batteries of techniques to cover different informants, places and also created cross-checking methods to get closer to the truth through successive approximations, and (v) it created direct contact relationship between the investigators and the local people

Participatory rural appraisal

In seventies and eighties, RRA dominated the scenario but for the basic flaw of non-participation and non-involvement, basic mode of RRA, however, remained obstructive

Outsiders used to go to the rural areas and obtained data from the local people. The data, the information and the knowledge was extracted from it. The outsiders or the investigators remained central. In late eighties, participatory rural appraisal participatory rural appraisal (PRA) techniques evolved. It presumed investigators as learners, catalysts and facilitators. In PRA, the knowledge is generated and articulated in a participatory way in which interviewing, mapping, diagramming, transacting, presentations and analysis are carried out by the rural people themselves. They identify the priorities, they give shape to their information, knowledge, attitudes and aptitudes and they are owning informations. PRA evolved as a forum of RRA in which the onus of initiative shifted from the investigator to the villager. PRA effort is a creative approach to information sharing and a challenge to prevailing pre-conceptions about the rural people's knowledge

What is participation?

Participation has a long history in development projects in involving people in certain aspects of planning and implementation in a programme. In the earlier programmes, initiatives in this regard distorted participation, created dependence and misleading impressions. Patronising participants in the name of participation resulted in failure of a programme after the project period was over. Jules Pretty developed typology for participation as under:

1 *Passive participation*: People participate by being told what is going to happen or has already happened.
2. *Participation in information giving*: People participate by answering questions posed by extractive outsiders using questionnaire, surveys or other approaches.
3. *Participation by consultations*· People participate by being consulted and the outsider agency listening to the views and define and modify the programme in the light of people's responses.
4. *Participation for material incentive* People participate by providing resources (for example labour) in return for food, cash or other material incentives
5. *Functional participation* People participate by forming groups to meet pre-determined objectives related to the project, which can involve the development or promotion of externally initiated social organisation, but remain dependent on external initiative and facilitators
6 *Interactive participation* People participate in joint analysis which leads to action plans and formation of new local institutions or the strengthening of existing ones
7 *Self-mobilisation* People participate by taking initiative independent of external institutions to change systems Such self-initiated mobilisations and corrective actions may or may not challenge existing inequitable distribution of wealth and power.

The project implementing agency should keep in mind various aspects of participation while promoting involvement and participation of the community in the watershed management programme.

Functions of PRA

1 Menu of methods
2 The primacy of rapport through behaviour and attitudes
3 Visual sharing

Basic principles of PRA

1. *Reversal of learning*: To learn directly and face to face from the local people gaining insight from their local physical, technical, social and psychological knowledge
2. *Learning rapidly and progressively*: Conscious exploration with the use of flexible methods and improvising, iterating and cross-checking the methods with the process of time.
3 *Upsetting biases* by patient listening, probing and learning through concerns, values, beliefs and priorities.

It means trying to gather information with trade-offs between quantity, relevance, accuracy, credibility and timeliness.

Fundamentals of PRA

(i) *Triangulation* Cross-checking and progressive approximation to the truth Normally, findings from different methods, places, times, disciplines, investigators are assessed and compared

(ii) *Seeking diversity* Looking for learning from explanations, oddities, discreteness in any distribution By maximising the diversity the information is enriched It is important to notice and investigate the contradictions, anomalies and differences The objective is to seek variability rather than averages

(iii) *Villagers as performers* The facilitators initiate a process of participatory analysis and the villagers take up the task of facilitating investigation, analysis, presentation and learning

(iv) *Self-critical awareness* Facilitators continuously and critically examine through behaviour

(v) *Personal responsibility* Facilitators take personal responsibility for what is done rather than relying on the authority of the rigid set of rules.

(vi) *Sharing* Sharing of information, ideas, knowledge, experiences between the facilitators and the villagers

The use of PRA techniques in watershed areas in last one decade has shown that

(i) villagers have a great capacity and skill to map, observe, compare, estimate, quantify, link, score, model and diagram,

(ii) the facilitator's behaviour and attitudes are important and that early relaxed rapport is easily established,

(iii) participatory diagramming is popular and powerful and visual sharing makes it more participative; and

(iv) PRA techniques and tools are very powerful and popular in conveying the field realities

Assumptions and basics of PRA

It is intensive, systematic but semi-structured experience carried out in a community by a multidisciplinary team which includes community also Range of techniques and approaches are used which are aimed at actively involving local people and enhancing their skills to enable them to analyse their situations and plan, monitor and evaluate an activity.

PRA is based on certain *basic assumptions* as under

1 That it is possible and desirable to involve local people, and increase participation in the development process
2. That learning from local people is possible
3 That range of circumstances and systems could be explored rather than just concentrating on statistical findings.
4 That issues can be investigated from different perspectives using a range of approaches.
5. That informal approaches are often more appropriate and can be changed as the work progresses
6. That multidisciplinary teams are more effective in the field

The *basics* of PRA include·

1. Learning from the community
2 Facilitation to enable the community to do more or all of the investigations, analysis and planning, so that they own the outcome and are empowered
3. Respect for behaviour, attitudes and knowledge of the community and confidence in their ability to do things.
4 Collecting and sharing the information and field experiences between the facilitator and the community.

Upsetting of the bias through self-awareness and in the community by actively asking the poorest, the least visible and the least articulate

PRA, as a process, emphasises on the establishment of a more equitable relationship between the facilitator and the community There is conscious effort made to empower the community Empowerment is through the creation of a participatory research process in which local people are viewed as active agents rather than objects The objective of the participatory process is to facilitate local people doing their own analysis through own situations PRA is exploratory and helps in assessing needs and prioritising problems Planning formulation, feasibility studies, monitoring and evaluation can be undertaken by using PRA techniques

Important tips for PRA practitioners

1 PRA is a continuous process Hence, PRA techniques should be used in the first, second, third and fourth years of watershed development and this process of gathering information should also be done during monitoring and evaluation
2 There are numerous PRA techniques and tools available to choose and opt from A judicious selection of such techniques should be done for a particular activity
3 PRA techniques should be used on different groups in watershed areas. This would facilitate cross-checking and triangulation and also facilitate rapport-building with different sections of the society
4 The facilitator should always keep time for the use of PRA processes and techniques in the watersheds
5 Make a checklist everyday before going to the field This would help in encompassing different techniques
6 Act as a team, i e , be unified and handle all areas together with other PIA members and the community
7 Be accommodative and inventive in handling techniques and tools These techniques

should be adopted to the field situations prevailing and existing in the watersheds.
8. Promote team building in the community Identification of self-help groups and user groups should be an automatic outcome.
9. Be flexible in the approach, so as to suit the needs and demands of the community/groups.
10 Explain the objective and methodology to the group in great details before starting the technique.
11 Make these techniques and tools as a game for the community. so that the community owns the technique and evolve, modify, rectify and include relevant aspects in the techniques on its own
12 Constant consultations and facilitations should be promoted The community should not feel left-out and ignored when it has started using the techniques Cross-checking of information should also be taken into consideration when the processes are going on
13 It is always helpful and useful to choose a permanent and unanimously accepted spacious place in the village.
14 It is preferable to start the techniques in early morning Though. the community should decide the timings for the techniques

Myths regarding PRA techniques

PRA is a simple process but the facilitator should be aware of the following *myths* regarding PRA techniques

1 *That it is quick* Devote time on each technique
2 *That it is easy* Impart skills of communication facilitation, conflict and negotiation at all stages.
3 *That any one can do it* Give insight into various organisational management. ethical and technical issues to other PIA members and impart skills to PIA members and the community
4 *That it is fancy* Be beware of complicated and unnecessary innovations and keep the procedures, processes and outcomes very simple
5 *That it has no theoretical basis* PRA is based on action, research approach so a balance between theoretical and practical aspects is maintained
6 *That it is just old wine in new bottle* PRA techniques are not fixed and rigid, so innovations, adoptions and modifications should always be promoted
7 *That the training is necessary* Avoid confusion by imparting complex training to PIA and the community Keep the processes and procedures simple and easy
8 *That people involved are neutral* Check out for political, ethical, social biases and pre-conceptions existing in the ethos of the participants
9 *That it is not political* Conflicts, disputes and tensions arising out of difficulties and perceptions about power, control and authority in the participants should be taken care of.
10 *That it is useful only for need assessment* PRA should also be used in planning, implementation, monitoring and evaluation of all facets of the watershed
11 *That it is universal* PRA techniques cannot be used universally over a group To respect heterogeneity, it is preferable to use them in different groups
12 *That it is only an entry point activity* PRA techniques give an insight into the prob-

lems, fears, opportunities, beliefs, attitudes, values, etc , existing in a community But it is a rapport-building measure and a continuous mode of flow of information. So, it should be used continuously through out the project duration.

Benefits of PRA

1. *Empowering poor and the weak*: PRA give confidence and authority to present need-based proposals, to make demands and to take action by the poor and the weak
2 *Diversification*: PRA increases and interplays of diverse and numerous perspectives of the community.
3 *The community process*: PRA helps in identification, appraisal, planning, implementation, monitoring and evaluation—all in a participatory mode in watershed management.
4 *The research priorities*: PRA helps in identifying the research priorities and initiating participatory research.
5. *Organisational changes*. PRA helps in indicating changes and modifications in the organisation, so that it becomes closer to the community's aspirations.
6 *Policy review* PRA helps in generating insights into the community and the facilitator so that policy reviews in the watershed programmes and management is possible.

Different PRA tools

A number of tools and techniques have been brought together under the umbrella of PRA. These techniques are *analytical, iterative, informal, exploratory, interdisciplinary and participatory*.

1. Social mapping and resource mapping
2 Ranking and scoring matrices
3 Venn diagram
4. Flow diagram
5. Timeline
6 Time and line transact
7. Pai chart
8. Seasonal calendar
9 Histogram
10 Resource modelling
11. Wealth ranking
12. Pairwise ranking
13. Preference ranking
14. Secondary data review
15. Direct observation
16. Structured interviewing
17. Focus group discussions
18 Analytical group discussions
19 Innovation/assessment
20 Historical profile
21 Livelihood analysis
22 Participant observations

23 Oral histories
24 Workshop and workshopping
25. Group walks
26. Stories
27. Case-studies and portraits
28 Proverbs
29 Economic analysis
30. Do-it-yourself activity profile
31. Portraits and profiles
32 Key probes
33. Future possible
34 Folklores, songs and poetry
35. Team interactions
36 Daily routines
37. Local management systems and resources, etc.

Interviews

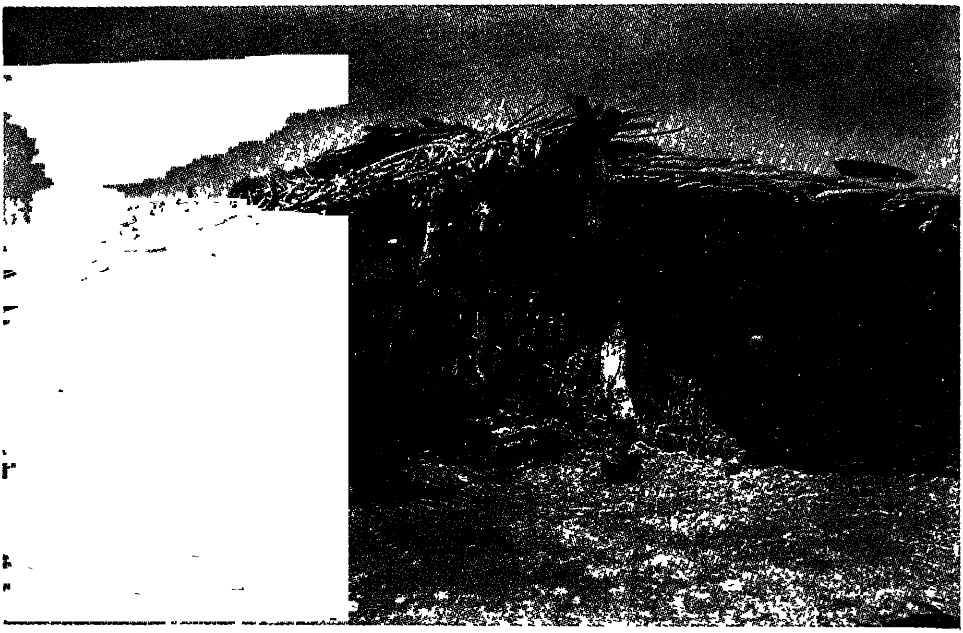
Interview techniques are important part and parcel of communication, more so in a rural development programme like watershed management where outsider's level of information and understanding about the field realities is limited Interview means a interaction between two or more persons and an exchange of views leading to a better understanding. Hence, interview is a forum of dialogue Earlier, questionnaires and surveys were used in which no real communication was taking place Such interactions were lop-sided with outsiders having unrealistic know-all presumptions Good interview is important for accurate insight in real rural situations, problems, traditions, beliefs, values, morals, customs, systems, perceptions, attitudes and aptitudes (see Plate 12)

The facilitator should include various desirable attributes while interviewing:

1 Sensitivity towards various moods, leanings, nuances, expressions, responses.
2 Accurate interpretation of various moods, leanings, nuances, expressions and responses.
3 Alertness
4 Progressive learning attitude.
5 Willingness to make and accept mistakes and to learn from them
6 Dynamic facilitation to make people talk and trigger off an authentic, interesting and useful flow of information.

Individual interview should be of specific, sensitive, confidential and personal in nature For example, an individual use of family planning method should be studied by an individual interview. The individual should be interviewed alone and in privacy to avoid disturbances and interruptions and to make him/her fully free to give an accurate information. So, it is desirable and necessary to create trust and faith between facilitator and the interviewee Group interviews are broader in nature and may be based on specific topics like health, education, agriculture, natural resources, etc The information sought is not personal or confidential in nature It is preferable to select a relatively secluded spot for group interview, slightly away from the village (such as in a field, on a hilltop, under a tree, inside a house, etc) Though, good group interviews can also take place in relatively busy

Plate 12 *Interviews may be misleading But observations about the household and its surroundings help to gather correct information about the socio-economic status*



spots Informal, casual or unexpected interactions often result in interesting and useful information (see Plate 13 a, b)

In a PRA it is desirable to get a cross-section of the people involved in the interviews These may include the following categories

1 Big, small and marginal farmers,
2 Landless labourers,
3 Artisans,
4 Other occupational groups,
5 Children,
6 Old age people, and
7 Women etc

Generally, a team of three persons is an ideal team for interviews Each person in the team should have a specific role, for example (a) interviewer (one who asks questions and queries), (b) recorder (one who writes down the information), and (c) observer (one who sees that the rules are followed and observes the interviewee)

The quality of the interview can be enhanced if a subject specialist is also included into the team For example, it is useful to include a doctor or a health practitioner as a subject specialist in a team when the information regarding illness patterns and health problems is gathered through interviews It is also important to plan out the interview process Understanding the need and objective of the interview is important Selection of the place, the team, the seating arrangement, framing out the questions, etc , should be decided before the interview (see Plates 14 and 15)

Plate 13 (a, b) *Knowledge about the local customs and traditions help in better understanding of the people*

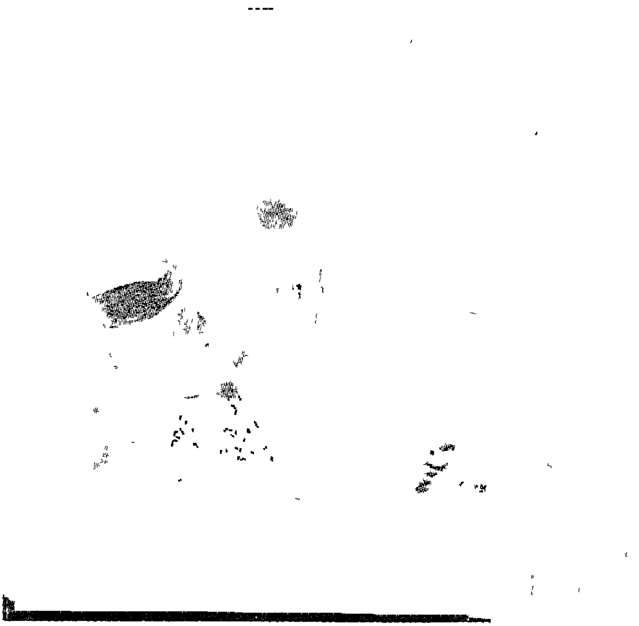


Plate 14 *House-to-house contact facilitates the building of a bond between the PIA and the villagers*

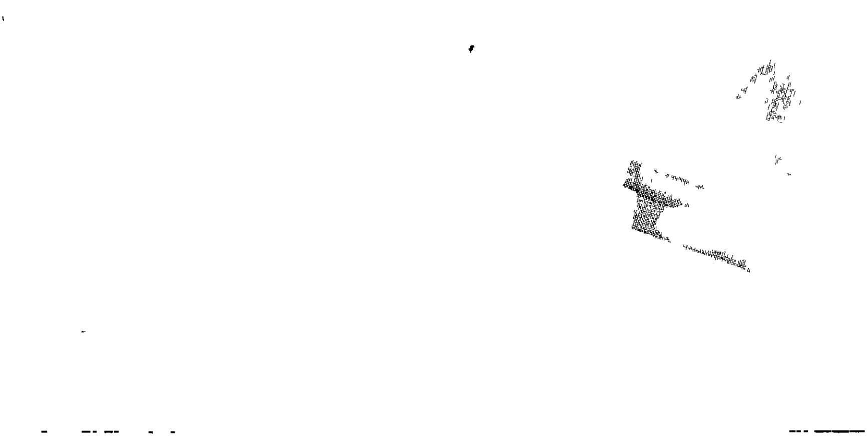


Plate 15 *Reaching to villagers and their worksite gives a correct idea about their individual and collective occupational problems*

Generally, note-pad and pen are sufficient for interview. It is simple to use keep local materials required for instant mapping and rough modelling

Do's and Dont's

Do's

1. Spend some time on formulating the interview team, fixing rules and responses, understanding the topic, selecting a spot/place and planning different aspects of interviews.
2. Show your interest and enthusiasm in learning from the people.
3. Be sensitive to the moods (like anger, anguish, boredom, enthusiasm, etc.) and build on it
4. Be alert and look for information and leads and follow them up
5 Follow protocol as required by the situation. Take prior permissions and appointments for interviews.
6 Create an atmosphere of confidence, trust and enjoyment
7. Involve everyone in the answering, especially those who are not very articulate
8. Avoid conversation monopolies.
9. Listen carefully and facilitate the information flow.
10 Constant cross-checking of information should continue
11 Terminate bad interview without feeling bad about it.
12 Record the names of informants and give them credit for the information they have given
13. Facilitate and control the interview
14 Avoid alienation from the group

Don'ts

1. Don't feel that the villagers are inferior.
2. Don't feel that there is nothing more to learn
3 Don't take the villagers for granted
4. Don't monopolise the interview
5 Don't lecture
6. Don't follow a single track of interest
7 Don't interrupt unnecessarily.
8 Don't misinterpret information
9 Don't allow talking at the same time.

Qualitative interviews

Types

Qualitative interviews with project beneficiaries and other key informants create understanding towards complex ecological, sociological, cultural and other circumstances Interviews also provide indepth understanding of the attitudes, perspectives, behaviour patterns, stereotypes, beliefs, morals, values, etc , of the target population They may help to generate various hypotheses and propositions which can then be replicated and revalidated with a wider population using a structured questionnaire

Quantitatively collected data is considered accurate and precise by the project staff, and qualitative interviews are considered impressionistic and flimsy. Hence, a conscious effort should be made to train and convince decision-makers and project staff about the utility of qualitative methods Structural interviews are rigid and preset (pre-determined questions to be asked in a given sequence), while qualitative interviews are open-ended and encourage free conversation and new avenues develop with the progress of interview They can be:

(a) *Informal/conversational interviews*: Interviewer has complete freedom and flexibility to explore broad subjects in informal or conversational interviews. They are encouraged to share their knowledge, views, experiences, values, informations, wisdom, etc New horizons may be discovered as the interview progresses. Such interviews, on the other hand, can be time-consuming, can result into irrelevant and repeating conversations. Resultant information gathered from the interviewee may not be comparable with that from another respondent Consentisation of information and evolution of consensus may be possible. Due to informal setting the respondent may be influenced by the personality of the interviewer.

(b) *Subject-focussed interviews*· Guiding questions are used to conduct such interviews. However, interviewer may phrase questions and may dwell on subjects or topics which are more relevant and important. If handled properly, the guide does not unduly constrain the flexibility in pursuing the conversation. A small preliminary study may reveal topics to be explored. The data or information gathered is more comparable and time-saving

(c) *Open-ended interviews* Open-ended questionnaire is used in these interviews which can take out diverse and explanatory responses The sequence of questions is not pre-determined and additional questions can also be asked It can be completed in short duration. Generally, an informal conversational interview can be immediately followed by a set of semi-structured, open-ended questions. Normally, following factors should be considered

1. the nature of the information required,
2. the skills and expertise of the interviewers,
3. the capabilities and background of the respondent,
4 time constraints, and
5 the nature of analysis and presentation planned

Guidelines for qualitative interviews

(a) *Initial contact* The style, attitude, manner and appearance of the first contact should break all barriers between the interviewer and respondents so that views, concerns and perceptions can be put forward clearly. Jargon and technical terms should be avoided The purpose of the enquiry should be explained in an appropriate manner to the respondents

(b) *Framing questions* Questions should be understandable to the respondents Similarly, questions should elicit detailed responses, i e , they should not be leading Questions with simply yes and no response options be avoided Questions should not be very lengthy, very technical, very open-ended Two or more questions should not be clubbed together, as it might confuse the respondents

(c) *Sequencing questions* It is advisable to begin with general conversation or with any subject which might create interest in the respondents Initial conversation helps overcome any initial reservations One should start with simple and less sensitive queries.

(d) *Role playing*: Respondents may be asked to assume only those roles with which they can identify Sometimes interviewer may assume a role. Role playing can help to reduce embarrassment in responding to sensitive questions.

(e) *Indepth probing*: It is required to take out details, sequence of events, elaborations, illustrations, clarifications. It is important to avoid annoying the respondents in the process The conversational tone must be friendly and pleasant, and the respondent should never feel that he is being cross-examined. NVC signals may be used to encourage answers. If a clear answer does not come even after two or three attempts, it should not be pursued, as it might create obstacles due to defence mechanism

(f) *Controlling the pace and direction of conversation*· The interviewer should try to fathom what the respondent is trying to communicate. Even certain off-track answers may hint at a pertinent idea or may express value system. However, if the interview is going seriously off the point, controlling in a polite and disguised fashion must be done NVC may help expediting and/or decelerating an interview

(g) *Impartiality*: It is important for an interviewer to be a good listener and a neutral observer. Any attempt to convert a respondent to a particular point of view should be avoided in all circumstances It should be clarified to the respondents that the objective is not to formulate value judgements but to collect informations and observations

(h) *Maintaining records* It is essential to keep proper records of the interviews, otherwise most information may be lost Use of tape-recorder is advisable But notes should also be maintained Coded/pictorial language may be used Pen down NVC and perceived thought processes Ideas, responses and feelings should have a place in the records. Notes should be taken in between the interview and/or immediately following the interview

Reliability of any interview depends upon respondent's level of knowledge and credibility, ability and willingness to respond to ulterior motives, desire to please interviewer, effect of recent events, etc Qualitative interviews should be tried on key informants as well They are knowledgeable individuals who can provide relevant and specific information and insight on certain subjects and issues. So, sarpanchas, village teachers, traders, grassroots government servants, cooperatives, local bodies, voluntary groups, etc., may be inerviewed as key informants.

Qualitative interviews in groups

Such interviews can be carried out by one or more interviewers with groups of varying size and composition They can be (a) community-based interviews (whole village or community), and (b) focussed-group discussions (few selected individuals)

(a) *Community-based interviews* Communities should be selected carefully Communities may be selected on expert advice based on informal sampling methods Number of respondents depend upon the population of the community's scheduled time for interview, local interest, etc Meetings should be well publicised If the participants in the meeting are not representative of the community or are present unwillingly, the reliability of the interview would be questionable. The size of the group must not exceed 30 and should be preferred at 15 It is important to use structured interview guides However, a rigid course of action should be avoided A team of interviewer should be carefully selected Team members, preferably from different streams, complement each other and can take down exhaustive notes and can put forward penetrating questions Team members should refrain from repeating, interrupting or confronting each other. A comprehensive strategy should be adopted to curb certain elite 'leaders' of the group taking over the role of responding to all questions on behalf of the community All community members at the meeting cannot be expected to participate in discussions, but every effort should be made to secure the participation of the majority. Opinions on certain sub-topics can be ensured by polling It should also be ascertained that group processes must not inhibit free expression of views or preferences. Sensitive questions should be refrained to be asked in the group. Post-meeting conversation should be encouraged and time (say upto an hour) should be earmarked for this.

(b) *Focussed-group discussion*: It involves smaller number of participants, and the stress is on spontaneous interaction among the participants Mostly a checklist of few sub-topics is sufficient in place of structured interview guide. The optimal number of participants can range from 6 to 10. It is necessary to select homogeneous group. If status differences (class, caste, landholding, etc.) exist in the group, then it hinder interpersonal communication. Efforts must be made to include diverse participants after discussions with numerous key informants Focussed group interviews should be conducted in privacy They can be conducted in school building, *panchayat bhavan*, with physically and psychologically comforting seating arrangement Generally, the interview should not exceed for more than two hours. Post-meeting conversation may also be carried out with willing individuals. The interviewer should convey the impression that though he understands the subject, he does not know the details Required allocation of time towards each sub-topic should be maintained. The interviewer should encourage all participants to come out with diverse views, perspectives, impressions about each sub-topic

Many people are reluctant to share their views in public. Numerous sensitive issues can not be discussed. Certain individuals tend to dominate the interview. Interviewers tend to pick up information which confirms their pre-conceived notion and their tendency for relevance and coherence may mar the diversity and may set aside inconsistencies in responses Group/qualitative group interviews, in particular, are less replicable than quantitative interviews/surveys

Observation of the participants

It requires direct observation of processes, behaviour, activity, relationship, network, etc , in the watershed. The participant observer becomes an insider without losing his status as on objective outsider It allows observation in natural setting and in totality. Sometimes, it reveals certain patterns, processes or phenomena which the respondents/ informants are themselves not aware of The observer should not enter the watershed area without any framework, otherwise it would be a waste of time The framework should include relevant and necessary variables only Also, help of other qualitative and quantitative interview techniques should be taken to reach to a framework (see Chart 7 1)

Generally, such exercise of participant observation is carried out by multiple observers and in multiple locations/situations. The number of sites may be limited to two or three. If the number of sites is increased, then the participant observation becomes costly and time-consuming It is important to select sites where the community is willing to accept the participant observer, where the activity/phenomenon is occurring in a perceptible scale, where the observer is able to observe into the normal activity of the group Proper timing should be selected

Chart 7.1 *Observation record form for WDC meeting*

1 *Seating arrangement.* What was the seating arrangement? Were women sitting separately? Were weaker sections sitting separately? Were the elite occupying front seats ?
2 *Attendance* What was the attendance ? Was it representative of the community ? Was quorum complete ? Were women members present ?
3 *Agenda* What items were on the agenda ? Were all of them covered in the meeting ? Was fruitful discussion and consensual discussion covered all the items ? What were the discussions or decisions which were not mentioned in the agenda?
4 *Conducting meeting·* Were secretary and volunteers present ? Who conducted the meeting ? What format was used ? Who took down minutes?
5 *Discussions* Were there free and frank discussions? Which questions raised confrontations? Which questions were discussed extensively ?
6 *Interest* Was there any interest in the proceedings ? Were some members bored or indifferent ? Did the attendance declined as the meeting progressed ?
7 *Participation* Did the majority ot those present participate in discussions ? Did a few members dominate the meeting? Did women and weaker section representatives participate ? Were there visible factions in the committee ?
8 *Decision-making* Were all the decisions unanimous? Was polling performed on some items? If so, where? Were decisions taken in earlier meetings fulfilled ? Were diverse options considered decision-making ? Were earlier decisions changed or reversed ?
9 *Other items* Any other

It is essential to establish sound initial contacts Observer may completely integrate into the community, may not act like a member of the community but participates in its formal and informal activities Similarly, observer may form close association with the best considered group, may spend time with different groups in the community, may maintain independent status and may be friendly to all, intimate to none

The description of the activity or process should be based on direct observation Observers reactions, ideas, notions, observations and insights during the exercise should be comprehensively documented Tentative conclusions should be drawn along with the progress of the exercise

Ideally, the observer should possess the following qualities

1 the capacity to relate to the people and the community,
2 sufficient maturity,
3 patience,
4 openness to the ideas and views,
5 familiarity with social, economical and cultural milieu of the area, and
6 training in participatory methodology

Participant observation requires a very high degree of expertise and skill It may be time-consuming Also, it may be useless in studies on heterogeneous population

Structured survey technique

Structured surveys are designed to generate qualitative data Before the survey, concepts should be standardised The questions to be addressed in the survey must be clearly specified through the discussions with the data users A careful review of other data sources within and outside the project area should be made This, besides decreasing load on data collection, will help in deciding methodology and survey design

(a) *Longitudinal survey*: It provides a time series of the measured variables and rates. A new sample may be adopted for each round or same sample may be maintained over time. Seeking data from new sample every time may be difficult. On the other hand, with same sample in all the rounds, there may be a chance of perpetuating an error, if the initial sample is not properly selected. Also, due to contamination effect, the repeated interviews/surveys may adversely affect respondents behaviour causing errors. No definitive recommendation in this regard may be made. But, rotating a third or half of the sample in each successive round is a reasonable choice

(b) *Cross-sectional survey* Data collection is completed in one survey round, with respondents chosen from each of the two or more groups

(c) *Comparison survey* In this, results of various sub-sets of the target group survey variables are compared to some selected classifying variables

Even when simple concepts are used in survey formats, definitions should be evolved to avoid ambiguity at the stage of data collection For example, rich or poor have to be defined quantitatively One may take land owners with holding more than 5 ha as rich and so on Difficult technical terms should be avoided in survey formats A caution should be kept so as the enumerators, intentionally or unintentionally, should not be able to change the definitions.

Similarly, project participants should be clearly defined In a watershed project, all beneficiaries are participants and all participants are beneficiaries *Recall period* used in survey is the elapsed time between the recalled event and the time of the interview Similarly, the *reference period* is that between 'opening' and 'closing' time of the event that is being recalled. Open-ended reference periods should be avoided, as they create numerous biases and faults Questionnaire should be properly structured, standardised, well-tested and sequenced appropriately

(d) *Questionnaire formats* Closed questions allow respondents to select from a set of pre-determined responses or options While open-ended questions may be answered in explanatory sentences, open ended questions may be more spontaneous but may be less useful for analysis They are very time consuming and the data sometimes is less reliable Closed questions restrict the responses but they can be coded and analyzed Open-ended questions may be tried on a set of project participants to determine the types of responses obtained Thereafter, such responses may be included as options in closed-ended questions Tabular format or two-way table may also be used Columns and rows may be depicted by different variables

Standard definitions and surveys should be applied and the enumerators should be well trained Technical, unfamiliar and ambiguous terms should not be used 'Yes' and 'no' options or multiple responses may be framed in a format Leading questions are phrased, as it creates an impression that a certain answer seems to be expected, so they should be avoided Separate questions should be asked differently and independently Use of convoluted and double-banded questions should be re-examined. Response set in the format can be avoided by varying the response categories for each question or by avoiding placing together all questions referring to the same topic Opening question should be interesting and easy and should be able to stimulate the interest of the respondents Dull or sensitive questions should not be included in the beginning of the interview The sequence of questions should be logical and the relationship between the questions should be clear to the respondents. Explanations may be inserted between two different set of questions Sensitive questions should be placed in questionnaire when the rapport between the enumerator and respondents has been ensured and they should be put where they are most relevant in reference to other questions Precise terminology and wording must be given in the questionnaire The questions can be summarised neatly in almost telegraphic form Sometimes, it would be helpful to translate in all languages that will be used in various locations If the reply to a question is a number or quality, a precisely defined space for recording the answer can be provided for Printed and well-laid down questionnaire format is preferred Questionnaire should be read and responses noted when the respondent is illiterate

(e) *Pre-testing* Before using the format on project participants, pre-testing on a few pilot respondents should be taken up to identify weaknesses, ambiguities and faults before it is finalised The pretest should detect the following aspects

1 Wording of questions
2 Construction of sentences
3 Question formats
4 Difficult questions
5 Same answers
6 Refusal rates
7 Time requirement
8 Interviewers' convenience
9. Coding
10. Usefulness of the data

The best results from such questionnaires could be gathered in personal interviews.

Participatory mapping and modelling

Maps, diagrams and models are important tools in planning activity Villagers have a great ability to represent their surroundings accurately and diagrammatically—whether they are literate or illiterate They also enjoy such activities It also generates a great deal of participation from the villagers. With minimal briefing and supply of the requisite materials, the villagers can prepare exhaustive and useful maps or models

Use of participatory mapping

(i) Quantum of information about socio-economic factors and resources of a watershed is easily available
(ii) Outsiders can gain insight into project participant's thoughts, beliefs, values, perceptions, attitudes, priorities, etc.
(iii) The locational details pertaining to each house such as the population, number of children, educational status, wealth, landholding, livestock, etc , can be depicted in the map/model.

(iv) In the case of resource maps, villagers are able to indicate to outsiders about landholding, ownership pattern, land use, productivity, physical features, land related problems, etc., in great detail.
(v) Trends of social aspects such as demography and resources such as vegetation are obtainable through mapping exercises by drawing maps in time series.
(vi) It is possible to study various aspects of village life during the course of a single exercise with various interesting topics
(vii) They form an excellent and powerful tool for participatory assessment, planning and monitoring of watershed projects at the micro level

Maps and models

There are two basic types of maps:
(i) *Social mapping*: household, village infrastructure, etc
(ii) *Resource mapping* land, soil types, forest, land use, irrigation, productivity, etc.

Mapping may be done on ground, on paper and by modelling. Mapping on ground can simply be done by drawing on the ground by using sticks, colour chalks, *rangoli* powder, etc. Such maps are visible to several people, are easy and quick, are participative and contain information on numerous aspects. Such maps can be corrected or altered easily and additions can be made with ease The ground map can use coloured powders or *rangoli* to indicate various subjects such as different features of the village layout, viz , streets, houses, location of different castes, household, health and nutrition, population status, land use, etc., or physical features, viz., hillocks, rivulets, *nallas*, etc.

Mapping on ground can be easily carried out Mapping on paper has similar uses and can be carried away as a document. Coloured paper, cut-outs in different shapes, etc., can be stuck on a plain background. This method was used to map the command area of an irrigation tank in Kilar district It showed clearly and accurately the different plots, shapes and sizes according to lay outs, ownership and survey numbers Maps on paper have the disadvantage of smaller and limited space, making extension or elaboration difficult. Also, it is not as participatory. Mapping on paper can be done with pencil or by using different coloured sketch pens Older and illiterate population may find it difficult to use pen and paper to prepare maps.

Modelling is three-dimensional and shows in greater detail the features of an area such as watershed, tank or command, etc. It is more participatory and can be lot of fun. Materials such as twigs, plastic sheets, grasses, matchboxes, etc , may be used for modelling Modelling is useful in land use planning, watershed planning, etc. Models can be historical or futuristic as well Models take more time. The participatory nature of mapping and modelling makes them extremely useful tool in understanding the field realities of watershed area and planning of watershed development In village mapping the villagers are asked to make a map of the current/existing situation prevailing in the village. Initially, a village layout is drawn followed by depiction of caste distribution and location, population, health mapping, socio-economic mapping, visible and invisible physical features, land use, ownership patterns, land productivity, etc (see Plate 16).

Various PRA exercises can be linked to one another. For example, matrix ranking of different types of soil based on type of crop, drainage, yield/productivity, land value, etc., can be completed and can be indicated on prepared social or resource map Similarly,

Plate 16 *Village modelling not only brings out the creativity of the villagers, but is the best way to break the ice and collect appropriate information about the natural resources and related problems*

different transact findings can be converged on the map/model of the watershed to represent indigenous technologies, problems, solutions and opportunities on the map/model It is also possible to combine social map with resource map, which would give more comprehensive and total picture Socio-economic situation of the community or resources in watershed areas could be compared over a period of time and could be related on the map. Villagers and planners can sit together and discuss with the map as focal point to arrive at a comprehensive and participatory plan for watershed development

Ranking and scoring matrix

Individual or group relative prioritisation of ranking elements of a single issue can be gathered from scoring matrices Key constraints, opportunities and preferences could be discovered. Such matrices provoke discussion on the criteria for selection or rejection and attempts to develop an understanding of the basis for making choices and decisions They are effective planning tool and provide basic comparative analysis of various elements

Methods

These techniques are most commonly practised PRA tools and have broad application Basic ranking, involves placement of elements in order of preference by writing, drawing or moving cards representing individual elements In this way preference on 1 to 10 scale can be arrived at Pairwise ranking compares each of these elements with respect to the other After lengthy discussions, scores on preferences are indicated and pairwise matrix evolves

Matrix ranking involves listing the elements down one side and the criteria on which they are judged across the top Criteria could be evolved from informal discussions or pairwise ranking. Each element is then considered in terms of each criteria. For example, tree species could be discussed in terms of fodder, shade, fuel, timber, fruit, availability and aesthetics. For each criterion, the tree species are ranked in order of preference Ranking works best if there are less than seven elements ranked for each criterion

Scoring matrix involves allotting relative weights to each preference and awarding each element points depending on its preference There may be cases where one tree species get good scores on shade, timber value and aesthetics, but due to lower scores on fodder, fuelwood, fruits and availability, could not score high.

Ranking or scoring system used in matrices should be clear to all facilitators and participants. A mix of positive and negative scores should never be used When ranking elements, they may be ranked based on 'rank' or 'importance'. In the first case, score 1 will denote the highest ranking, while in the second case 10 will denote the highest ranking. A number of different methods, depending upon context and desired output, are used and applied with individual strengths and weaknesses In free scoring, no limit is placed on the scores for each element against each criterion In closed scoring.

(i) scores between 0 and 10 may be allotted to element for that criterion,
(ii) a fixed number of points can be awarded for each criteria and these are distributed between the elements in that row or column in relation to their perceived importance, and
(iii) a fixed number of points is allowed for the entire matrix, and these must be distributed between both elements and criteria.

Free scoring has the advantage that elements and criteria score according to their importance more appropriately. On the other hand, closed scoring is restrictive, so the results are always relatively invalid due to moderation done with the scores.

Informations received from other related exercises can be triangulated with ranking and scoring exercises.

Applications

Matrices have been applied as part of RRA or PRA in numerous contexts. They appear most commonly in association with wealth, agriculture and forestry. Some examples are.

(a) Water (preference ranking of different sources for domestic or irrigation purposes)
(b) Fuel types (preferences and problems, comparisons in urban/rural)
(c) Food types (preference for staples, fish vegetables, etc)
(d) Credit (preference for sources, access, problems)
(e) Income generation (preference for activity, problems)
(f) Institutions
(g) Project (preferences, priorities, interventions)
(h) Health (facilities, food and nutrition, diseases, symptoms)
(i) Livestock (preferences, fodder types, species, diseases)
(j) Agriculture (soil types, production problems, species, varieties, pest damage, marketing, etc)
(k) Forestry (species, preferences, advantages, utility, varieties, forest products, medicines, management systems)
(l) Problems and opportunities
(m) Gender issues

There are numerous and innovative ways of conducting matrices. Comparative matrices have been made, for example, between male and female gender. In ladder ranking, participants record their own location on a ladder illustrating past, current and potential conditions with participants deciding which rung is closest to their situation.

Participation, materials and timing

These exercises are generally carried out in group Large number of participants can participate when matrices are drawn on the ground, constant discussions and consultations bring out points to modify elements, criteria or weights allocated, etc It is important that facilitator should not take prime importance shunning observations of the participants. Larger groups may be broken down into homogeneous sub-groups for comparison or accuracy of data. It is important and significant to break down matrices based on gender

Almost any material can be used for constructing a matrix or drawing a ranking. Drawing and ground matrix are more visible and participative and are less intimidating for illiterates Elements and criteria may be written on the axis Ranking or scoring may be drawn in numbers or indicated by the number of smaller objects placed in that box (such as seeds, nuts, grains, stones, beans, etc.)

Usually, matrices are not the initial PRA technique to be used on the community It is advisable to take up matrices after social/resource mapping or transacts Pairwise ranking are conducted first, followed by more detailed preference ranking or scoring matrices (Figure 7 1)

Figure 7.1 *Preference ranking on a scale of 0-5 (micro-watershed Dumpada, Jhabua) The villagers preferred Ber (Zizyphus sp) and Neem (Azaderachta indica) over other species*

PREFERENCE RANKING

	Fodder	Shade	Fuel	***** value	Fruit	Availability	Aesthetics	Scores
Teak	X	••	••	••• ••	X	••	•	12
Bamboo	••	•	•	•• ••	X	•••	•	12
Eucalyptus	X	•	••	••• ••	X	••	•	11
Neem	••	••• ••	••	•••	•• ••	•••	••	21
Shishum	•	•• •	•	•••	X	•	•	10
Khair	••	••	•• ••	•	X	•••	•	13
Ber	•••	•• •	•• ••	••	••• ••	••• •	••	23
	Ber	Neem	Khair / Ber	Teak / Eucalyptu	Ber	Ber	Neem / Ber	

Strengths and weaknesses

Matrices are generally easily understood and often are self-sustaining. They provoke strong discussions and deliberations. Once the concept has been grasped, it can be applied easily and quickly to other issues. Gender and class implications should always be considered, as they have different preferences. Using these techniques, reasonable comparisons can be drawn without having to push for different or sensitive quantification Matrix can highlight anomalies (such as a high scoring tree species may be undesirable for one specific use). It should also be conducted with different sub-groups for comparison Negative and positive criteria should never be mixed Facilitators and participants should all understand exactly what method is being used. All the criteria should be clear and agreed upon by all participants, otherwise there would be lot of confusion Scores from columns or rows should not be summed up as this is misleading, unless the significance is understood The choice of scoring a crop may not be determined by market forces or preference Good facilitation is important but sometimes they appear to push their own criteria onto villagers

Venn diagrams

Venn diagrams, also called *chapati* diagrams, are usually used to depict key institutions, individuals within a community and depict interaction between them This technique, once used in RRA, forms an integral part of PRA tools basket The institutions or individuals represented in venn diagrams are key players in decision-making or are the ones which affect multiple aspects of the community

Venn diagrams have been used to describe

(i) the roles and significance of various institutions,
(ii) levels of communication of various institutions,
(iii) the role of project agency and their interventions,
(iv) potential roles for new organisations,
(v) missing links between existing organisations, and
(vi) potential for working through existing organisations

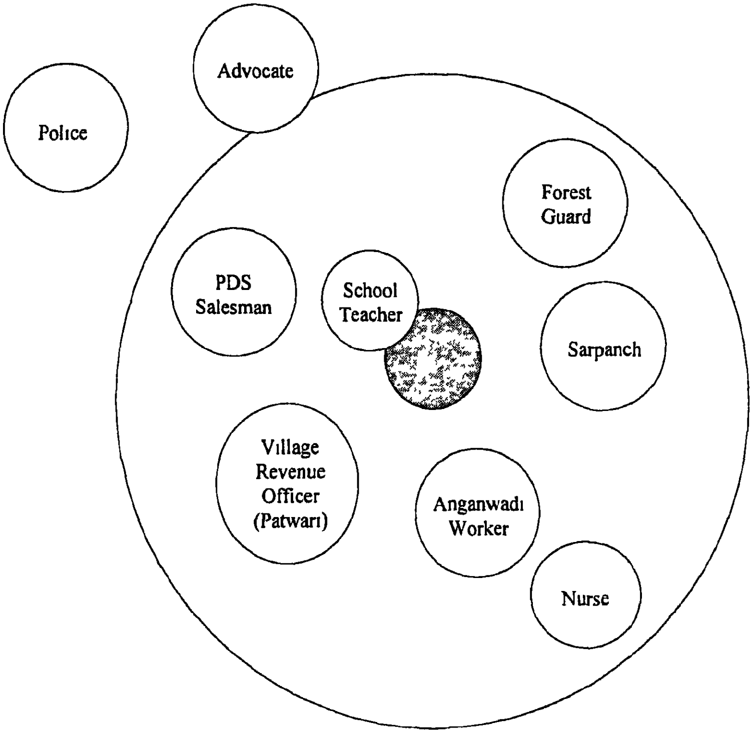
In Venn diagrams, the size of the circle represents the importance, significance or power of that institution and The level of interaction with the community is represented by the distance from the centre and the degree of overlap with the village circle The degree of beneficial influence of the institution is also represented by the distance. Discussion on communication between formal and informal groups and their levels of cooperation may be initiated Venn diagrams indicate community's perceptions about significance and importance. Since the perceptions regarding the institutions vary, therefore comparison between different sections of the community should be carried by using the technique on diverse sub-groups

Methods

The institutions can be written, drawn or symbolised Various materials such as chalk, pen, pencil, paper circles (pre-cut) of variable sizes can be used Participants are asked to list all the institutions that are significant to the subject under discussion. This list can then be used Alternatively, an open discussion can evolve into focussed discussion regarding institutions, with visual depiction taking place along side

The centre point is always represented as the community (or individual or group in question), and circles are drawn or placed around that. The village may be represented as a very large circle and institutions are placed in, overlapping or around this, depending on the interaction. Alternatively, the village may be a smaller circle, and the distance is the representation of interaction If distance is indicating influence or utility, then the ability to overlap is less important Circles may be linked by lines with the thickness of the line representing proximity and influence (Figure 7.2)

Figure 7.2 *Venn (Chapati) diagram (micro-watershed Khatama, Jhabua) School teacher is the-closest government functionary to the villagers Villagers perceive police as important but its need is not felt as the village is peaceful*



Triangulation has been carried out by presenting diagrams back to larger groups or groups with varied composition Institutional ranking/scoring may be used to triangulate A variety of matrices, rankings, pie-charts, etc , can be used to discuss related subjects

Applications

Venn diagrams have been used to explore a variety of linkages. All the institutions which affect the functioning of the community are depicted diagrammatically by the villagers This would create a general picture of organisation and individuals which are perceived to be significant Venn diagrams are used to examine

- informal groupings,
- institutional aspects of conflict/dispute resolution,

— examination of the role played by outside agencies, and
— examination of the role played by village agencies and institutions

Pairwise ranking

It is an early technique from RRA, which compares pair of elements It is used for learning about rationale behind decisions and act as a key to understand, say, natural resource use Through an increased understanding of priorities, pairwise ranking can highlight relevance and appropriateness of any interventions Comparisons between groups, based on gender, occupation, age, class or history, are possible with identification of group preferences and priorities.

Method

After a discussion in which several items relevant to a particular topic are covered, items are compared two by two until all combinations are exhausted Mostly, a grid is drawn with elements along the axis The participants are encouraged to write or draw or symbolise their preferences onto the grid. The participants are asked to list (in ranked order), a set of items on a specific topic and pairwise ranking is used to discuss results It is possible to count the occurrence of each item and a ranking could be evolved alternately. The participants are asked to rank the items themselves Discussion may be entered accordingly Pairwise ranking can be followed after transact walks as well

Applications

Mostly it has been used in the field of forestry and agriculture Tree species preferences, crop preferences, fertiliser preferences agriculture and tree problems may be explored Also, expenditures, sources of income, sources of credit, irrigation, general problems and potential, etc , can also be explored by using pairwise ranking

Participation may be increased by allowing participants to fill the grids A cross-impact matrix can be created listing the same factors on each axis and comparing the effects of each upon the other Thus, one box assesses the effect of availability of irrigation on income levels and on the other axis income levels on irrigation

Participation, materials and timings

Pairwise ranking is discussed with formal or informal groups of different gender, age, classes, castes, etc , separately for comparison feedback Ranking results from one group can be used to promote discussion with another group

Objects with good visibility, when used, assist greater participation and access from all angles and working on the ground Many materials are suitable like chalks, pen, papers, etc Pairwise ranking has often been used as precursor to more detailed matrices Pairwise ranking may be used after wealth ranking, transact walks, mapping, etc , to dwell into specific details

Strengths and weaknesses

Pairwise ranking almost always stimulates discussion and elicits detailed knowledge and understanding, especially where participants have expressed a lack of preferences for specific items or have no detailed knowledge of the subject The processes in pairwise ranking are as important as the results

Items are likely to be multifunctional and so simple comparison without criteria may not be simple Access to basic amenities which determine preferences may also create problems in reaching group's consensus Similarly, some comparisons are insignificant Sometimes discussions and deliberations are more useful and valid than ranking Pairwise comparisons become tedious and confusing if a lively discussion does not evolve To avert the risk of boredom, number of elements in the exercise should be limited to 5 or 6 Participants may loose interest if the visual impact is lost and the discussions are not lively

Timelines

Timelines are used to identify and trace historical sequences of events, generally over a period of months, years or decades. Significant events and resultant major changes may be identified They are used as a potent and powerful PRA tool for.

(i) identification of sequences of significant events/changes over time,
(ii) monitoring the impact of these identified events,
(iii) identification of coping strategies,
(iv) understanding past interventions, and
(v) providing a reference point for trend analysis

Timelines examine general as well specific activities, taking into consideration periods of activity and/or inactivity as well as individual events Timelines promote discussion on events, consequences, etc , in a historical time frame (see Table 7 1)

Methods

Most commonly used method is to match events or activities with a date written on one side of a line and the event on the other Dating can be depicted on the time line by

(i) breaking the line into regular intervals (such as, years or decades), and
(ii) dividing the line according to the timing of the events

Date/time or events are usually written down by the participants after discussions Sometimes symbols may also be used In front of an illiterate group, events are just placed in chronological order Literacy or familiarity with exact dates is not required in this method Questions around the information given may be pursued or feedback discussions focussing on the timeline may be initiated with other groups Time trend diagrams and graphics, historical transact, matrices, venn, pies, maps, etc , can be used for triangulation and can be produced for specified time in the past Sometimes, related information may be recorded alongside the timeline, usually to highlight and relate with chronological changes. Information, so obtained, may be expanded by using greater variety of visual methods

Applications

Most common subject studied on timeline is the examination of village histories, where significant and important events in the development of the village are taken into consideration Leaderships, administrative/political events, religious events, changes in the natural resource-base, development of infrastructure, emergencies and natural disasters, and introduction of the firsts (TV, radio, bicycle, tractor, etc) are considered in such village histories Personal histories including influencing external factors and constraints can also be examined. Project histories such as plantations, irrigation schemes, etc , may also be considered. Climatic variations, yields, stock numbers, fishing activities, major economical or commercial ventures may also be examined using timelines.

Table 7.1 *Timelines (micro-watershed Mod, Jhabua)*

Year	*Social profile*	*Income levels and agriculture*	*State of forest and coping strategies*
1947 to 1960	15-20 households, no land records, no migration	Low labour wages, barter system, kodo, kutki, kulthi as main crops rainfed irrigation sharecropping	Forest and CPRs provided fodder, fuel and NTFP, much dependence on forest produce in non-agricultural seasons Biodiversity rich, wild animals/carnivores seen No disputes
1960 to 1975	25-30 households, title disputes, few temporary migrations, first bicycle in the village	Wage rates equivalent to 2 kgs of maize per manday Maize and gram introduced Irrigation through wells started, sharecropping continued Land alienation major problem	Degradation of forest areas due to rise in social activism, rights of the villagers checked due to nationalisation leading to alienation and outcry Demand-supply gap of fuelwood and fodder visible, wildlife starts disappearing
1975 to 1985	60-70 households, initiation of land reforms, mass migration to other States due to severe drought in 82, 83 and 84, first radio in the village	Wage rates equivalent to 3 kgs of maize per manday Wheat introduced Irrigation through diesel pumps and FYM used extensively	Forests cleared and encroached upon, scarcity of fuelwood led to digging up of roots, community lands completed encroached number of species disappeared, wildlife restricted to rabbits and birds, conflicts control of natural resources started
1985 onwards	150-180 households, land settlement held habitual and opportunistic migration, first TV in the village	Wage rates equivalent to 5 kgs of maize per manday Rice, soyabean and cotton introduced Lift irrigation schemes came into the village Use of urea prevalent No of landless increased	Necessity leads to forced conservation by informal groups and individuals, severe scarcity of fodder, encroachment regularised to a large extent No wildlife 1990s saw emergence of JFM in the village

Participation, materials and timing

Generally, timelines are created using one or two key informants who are old and local residents of the area Other participants may help the key informants in modifying certain events or dates Groups of size less than 10, usually mixed sex groups, may be used in preparation of timelines and increase the reliability of the information In small groups, the participation is maximised and range of perspectives could be evolved A wider community may be divided into smaller groups and timelines created by sub-groups may be discussed and merged into an agreed overall timeline Sub-groups may be chosen randomly or may be deliberately selected on gender or socio-economic considerations

The most common materials used are paper and pen, with the lines drawn on sheet of paper and the dates and events filled on this Participants may identify events on separate pieces of paper which can then be stuffed around as other events are recollected and fitted in.

This PRA technique is advantageous to be used and conducted fairly early. It is useful as an ice-breaker. Timeline provide historical perspective to the participants which could assist them in understanding the future circumstances Timeline acts as a source of reference for historical events and opens up discussion about the past, which can then be used as a basis for projection into the future.

Strengths and weaknesses

They can be used to relate individual, cultural, economical, political, social, agricultural, environmental events in historical context. A greater depth of analysis could be generated by combining timeline with illustrations A single individual may hijack the proceedings from the group. This tool may become facilitator-driven when used in an illiterate group.

Seasonal calendars

This is an older method in PRA which is called regionality diagramming or seasonality analysis. They present large quantities of diverse information in a common timeframe, by showing in a diagrammatic form the activities, constraints and opportunities which occur during the annual cycle. They are used to develop an understanding of local livelihood systems and to help identify the months of greatest difficulty, vulnerability or other significant variances which have an impact on people's lives

Methods

Most commonly, the months or seasons are indicated along one side of the diagram and the corresponding activities or events are indicated on the other side. In another method, months or seasons are listed down the left or the right side of the diagram with corresponding activities indicated alongside.

It is important to identify months or seasons that everyone is familiar with. It is not necessary to start the calendar with January. It may be appropriate to start the calendar with the beginning of a season or the agricultural year or start of an important festival In practice, most calendars follow a twelve months pattern. Symbols may be used to represent months in a calendar, and it makes it more usable for illiterate For example, in Jhabua month of sowing (June) is depicted in PRA by grains/seeds, month of harvesting (October) is depicted by sickle, month of rains (August) is shown by clouds etc.

After establishing framework of the calendar, the amount of duration relating to the various categories are added Sometimes, regional trends cannot qualify, then rough estimates can be calculated by comparing maximum and minimum in the cycle Triangulation is usually carried out by probing for inconsistencies and inadequacies. Informations can also be cross- checked with data gathered from transact walks

Applications

The calendars are traditionally used in rural context to identify the causal relationships between climate, agriculture, employment activities and other seasonally varying phenomena Emphasis is put on identification of period of stress and crisis, so that remedial measures may be thought of. It also helps in identifying lean season and accordingly new activities in the project may be started and initiated Seasonal calendars have been used to investigate:

(a) periodic migration,
(b) periods of high infant mortality,
(c) illnesses common at different times of year,
(d) periods of fodder availability and scarcity,
(e) periods of cropping activities,
(f) periods of crop pests and diseases,
(g) periods when flood or drought occurs,
(h) seasonality of NTFP collection activities,
(i) seasonality of income-generating activities, and
(j) type and quality of food available at different period.

Seasonal calendars can also be used to indicate trends over an average year Relative change over years or decades can be explored and effectiveness of a particular intervention of the project may be investigated. A whole series of calendars with various events become more evident when the links between different parts of the system become clearer Calendars based on livelihood systems are less commonly used. The calendars have evolved from agro-system to focussed areas such as livestock or health More detailed information can be gathered from detailed and more focussed calendars Participation can be encouraged by assembling and preparing composite calendars Similarly, situations in the past can be represented in the same calendar Seasonal calendars can be presented in circular as well as in linear form (Figure 7 3)

Participation, materials and timing

Seasonal calendar may be done by a mixed group of local people or by stratified groups based on gender, age or socio- economic conditions Children can eagerly and enthusiastically participate in the activity Seasonal calendars drawn on ground are more participative

Seasonal calendars are usually drawn on the ground, using chalk, leaves, dry grasses, stones, sticks, nuts, seeds, etc Relative changes in quantity are depicted by number of seeds or stones or by different lengths of sticks *Rangoli* powder may also be used Pen and papers may also be used, but it may be alien for the rural and illiterate participants

This exercise is usually conducted in the middle of the PRA, rather than as an initiating or concluding activity This exercise is useful after establishing rapport with the community and the important issues for seasonality have been identified

Strengths and weaknesses

It enables group discussions on the basis of the diagram and creates a visual pattern of activities throughout the year They can demonstrate links between different seasonal variables Participation levels may be low if confusing and complex composite calendars are used

Daily schedules

They are important for identification of daily labour patterns Work types and distribution

Figure 7.3 *Seasonal health calender (seasonality with scoring) (micro-watershed Dhamni Nathu, Jhabua)*

DISEASES MONTHS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FEVER				●●	●	●					● ●●●● ●●●● ●●●●	●● ●●
COLD AND WHOOPING COUGH	●● ●●										●●●● ●●●● ●●●●	●●●
MALARIA				●●●● ●●●●		●	●●●● ●	●●●● ●●●	●●●● ●●●● ●	●●●● ●●●● ●●	●●●● ●●●●	●●●● ●●
DIARRHOEA				●●●● ●●●● ●●●●	●●●		●●		●	●●●● ●●●● ●●●● ●●●● ●●●● ●●●● ●	●●●● ●●●● ●●●● ●●●● ●●	
MEASLES				●●●● ●●●●	●●●● ●●●● ●	●●●● ●						
JAUNDICE	●●●● ●●	●●●● ●		●●●● ●●●●								
VOMITING	●	●●●		●	●●●● ●●●● ●				●●●● ●●●●	●●●● ●●●●		
SCABIES		●●	●●●	●●●● ●●●● ●●●● ●●●●	●●●● ●●●● ●●●●		●●	●●	●●●	●●●		
TETANUS									●	●●●● ●●●●	●●●● ●●	●●●● ●
MONTHS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC

of work load throughout the day can be depicted. Daily schedules of different individuals and households could be analyzed The main reasons for creating daily schedules are·

(i) to document activities,

(ii) to document the timing of activities and demarcation of periods where more than one activity are carried out concurrently,

(iii) for comprehension between different daily schedules,

(iv) for discovering suitable links for meetings and training session, and

(v) for discussing new activities and their implications for time use

Daily schedules have also been used to illustrate mobility and periods spent away from the home

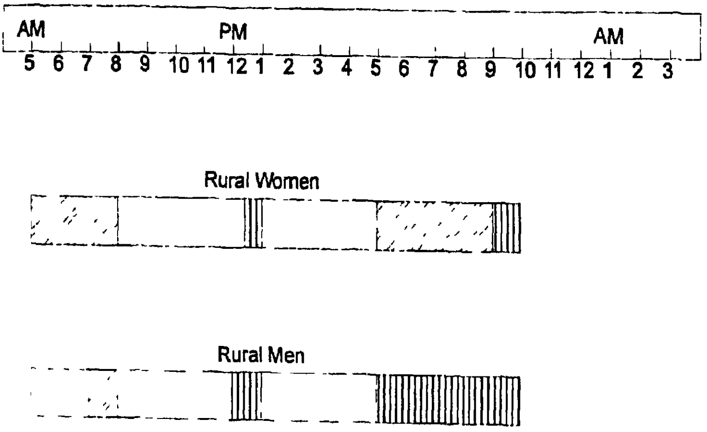
Methods

Daily timeline covering a period of 24 hours is prepared with the help of participants. The day may be sub-divided depending upon the participant's perception in hours or in morning, afternoon and evening, or by times when types of work changes. Different daily activities are placed along the time-line. The activities may be written or symbolised against time blocks or they may be graphed Written explanations may be included for elaborations and deliberations.

Alternatively, extensive symbols and relative estimations of time can be used in daily schedules. Symbols are placed along the line depending on the order in which activities are undertaken each day. Free or fixed scores or number of elements can be allocated to indicate the proportion of time spent on each activity at that stage in the day. In place of attempting for chronological order, the total time each day for every activity can be estimated by grouping and clubbing all the time that activity is done. Second method is more useful for societies where time has different connotation and group is illiterate.

Timings can altogether be abandoned and daily activities may be worked out in extensive details, without considering relative time expenditures. The emphasis is less on hourly routines but more on the sequences of events. In certain religious communities the timing of other events may revolve around timing of prayers, and in fishing communities much of the daily schedule revolves around the fishing activity The utility of the schedules and degree of information is ascertained by indepth discussions Schedules can be combined with seasonality. Daily schedule matrix can be prepared on two-dimensional chart and variations in routines can be explored throughout the year (Figures 7.4 and 7.5)

Figure 7.4 *Daily routine diagram (micro-watershed Alipura, Jhabua) Men have more time for self, while women work from 5 am to 9 pm with hardly half-hour afternoon siesta*



Applications

Gender differences in workload can be explored by creating daily schedules in women's group Agewise and incomewise sub-groups may be used to assess workload of women in

Figure 7.5 *Daily routine of rural women (micro-watershed Panchpiplaya, Jhabua)*

I. *Field Activities of Rural Women*

(a) Women weed the field once ploughing is over.
(b) For orchards growing papaya, the women arrange the soil to heap them together near the roots of papaya plants
(c) It is the women who carry water in earthen pots to water the fields at least 10 to 20 times a day as required
(d) They carry food, water and 'hukka' pipe to the field for their household male members
(e) They carry fertilisers of different varieties to the field
(f) They pick the grass growing in the field and decompose it for making fertilisers.
(g) In orchards growing papaya they prepare the soil, plant the seedlings, water them and pick weeds.

II. *Daily Routine of Household Activities of Rural Women*

(a) Early morning up and reciting prayers
(b) Sweeping the front portion of the hut
(c) Taking the cattle out from its shed and giving it fodder
(d) Taking out goats and tying them in places where they can eat on their own.
(e) Sweeping the back portion of the hut
(f) Cleaning utensils
(g) Cleaning the children and their teeth
(h) Fetching water for cooking
(i) Preparing food for household members and serving them
(j) Getting the children ready and sending them to school
(k) Fetching water for bathing
(l) Cooking for lunch and serving
(m) Giving fodder to cattle and goats
(n) Tying them at places where they can find more food
(o) Sweeping and cleaning the house
(p) Fetching water for cooking
(q) Cooking food for evening and serving
(r) Reciting prayers before sleeping in the night and going to the bed

III *Other Activities by Rural Women*

(a) To weave mats from local grasses and sell them
(b) To weave fences from the bamboo sticks cut by them and to sell them
(c) At the time of ripening of fruits like bel, mango, jackfruit, tamarind, ber etc , the women help in collecting them while the men pluck them from trees

different age and income groups Within one gender, differences are noticeable between the young and old, the rural and urban, the rich and poor, etc Differences in perceptions can be emphasised by comparing men's idea of women's daily schedules and women's idea of men's daily schedules Daily schedules of relevant self-help groups and user groups should be prepared to understand their commitments (see Plate 17)

Plate 17 *Active women's participation in PRA exercises add new facet to collected information*

Participation, materials and timing

Single gender groups are necessary as activities vary considerably between men and women Evolving consensus in a smaller group is possible Daily schedules are useful as an initial PRA exercise It is simple to apply on participants in the early stages This exercise is less threatening as the subject is familiar and involves routines They can follow seasonal calendars or livelihood analysis Pen, paper, and materials like twigs, stones, grains, etc , can be used This exercise is a strong tool, but has a danger of becoming routinised.

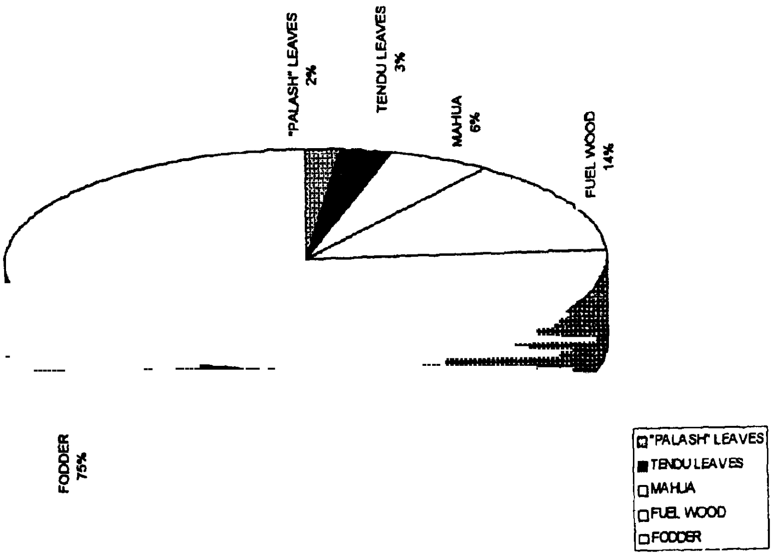
Pie charts

Pie charts can be used to generate discussion and information about proportion (as part of a whole) in diagrammatic form They have been used to examine both factual issues such as ethnic groupings and people's perceptions

Methods

The pie or circle is divided into segments which are proportional in size to the importance of that particular element The discussion over proportions is carried out and agreed upon before the pies are marked on the chart Similarly, movable lines (sticks) can be marked during discussion and discussion centres around changing these lines Since, most of the population is not very familiar with the concept of proportion or percentage, the process should be made easier One may use phrases like "from a rupee, how many paises worth is..." or "out of 100 stones or nuts how many stones or nuts are spent on it". Alternatively, piles of sand or grain have been used, and sub-piles moved around, divided and re-divided. Pictures, drawn by respondents, to indicate the slices of the pie help in initiating discussions. Triangulation through creation of pie charts on various groups is common Maps, transacts and historical diagrams relate data and information useful for pie. Pie charts are similar to any other exercise found in PRA, it is only the visual depiction that varies (Figure 7.6).

Figure 7.6 *Pie chart (micro-watershed Hardaspur, Jhabua) Out of total forest products collected from neighbouring forest areas, 89% constitute fodder and fuelwood women almost exclusively collect them from their natural resources*



Applications

Numerous issues can be explored by this technique·

(i) Proportions of population within village like livelihood analysis, land ownership, educational levels, literacy rates, use of health care facilities, ethnic composition, age group composition, etc

(ii) National resources like agricultural land under different crops, forest land under different species, sources of water used, numbers of stock owned, land use allocation, regeneration of various coppices from root stocks, etc

(iii) Household information like household income, household expenditure, crop cultivation costs, plot level agricultural analysis, etc.

(iv) Individual or community perceptions

Pie charts may also be developed over time or on gender basis A number of different individual 'pies' can be brought together and discussed and a cumulative pie agreed on One piece of a pie can be further sub-divided Finally, dual pies can be developed where multiple rings encircle each other and each layer depicts a different though related issue or period in time

Participation, materials and timing

At community level, mixed groups are considered for pie charts, since range of inputs are important. At household level, either individuals or members of the same household are used Homogeneous groups are advocated for looking at specific issues to examine the influence or impact These are versatile in their location within PRA. Findings from social mapping, land use mapping or wealth mapping may be used for pie chart There is no real restriction on the type of materials used in making pie charts. Circles and lines can be drawn just as easily on the ground as on paper. Depending on the method used, a number of materials like grains, nuts, stones, etc , can be used to illustrate the size of pieces

Strengths and weaknesses

It is difficult to explain the idea of proportion to the community or the participants This can, though be avoided by imaginative facilitation There can be a cultural or social barrier, since most cultures do not divide pies in the same way If flexible materials are not used then the incentive to discuss is lost The strength of a pie chart lies in its versatility It helps in discussing and understanding distributions and also dynamics within community It also provide for clear and visible comparisons Discussions on relative amounts and percentages add new perspective to the understanding of community and household dynamics

Network and flow diagrams

There are a variety of ways to indicate the interlinkages and flow between different components in diagrammatic form These diagrams have been used to discover and analyse impact and activity flows and interrelationships between different groups and issues Constraints, problems and opportunities can be discussed Similarly, discussions on the interconnections and subsequent effects of specific interventions can be possible

Networks and flow diagrams have been used within the PRA to

(a) identify significant issues,
(b) illustrate relationships between elements within the system,
(c) illustrate causal flows and linkages,
(d) highlight gaps in indicating potential connections, and
(e) identify points at which vicious circles can be broken

Both broader and specific issues can be studied It is possible to undertake comparative analysis.

Methods

There is a great variation both in the type of information depicted and the way in which interlinkages are represented The 'network' consists of a central circle with elements radiating from it This may be complete, either with or without, further explanation or continued with secondary elements radiating from this Simple flow diagrams consist of a single sequential chain Single issue or element is broken down into successive sub-elements Once a number of linkages between elements are introduced, distinctions are blurred Number of elements are shown with interrelationships, links and flows which illustrate the complexity of systems, whether relating to the natural or human environment Experts recommend to limit the expansion of the diagram The topic or the subject should be clear and specific The number of boxes or elements should be limited to under 10 (or at most under 15) If the diagram becomes complex, it is incomprehensible. Discussions, around the diagram with other people, lead to greater possibilities for triangulation. Flow and network diagrams are often born out of mapping or other exercises and there is opportunity to cross-check the results from these techniques (see Plate 18)

Plate 18 *Flow diagrams depict inter-relationship among various factors It also brings out collective analytical understanding*

Applications

This technique is useful to elaborate subjects involving linkages, causes or outcomes Analysis of systems, problems, opportunities, coping mechanisms, institutional interactions and decision-making strategies are possible The networks and flow diagrams are applied to study

(a) household systems, farm systems,
(b) credit systems,
(c) agriculture/production systems. marketing systems,
(d) indigenous knowledge systems,
(e) forest management systems,
(f) community level enterprise systems,
(g) nutrient flows,
(h) resource flows, incomes and expenditures,

(i) household energy flows,
(j) health and disease,
(k) causal diagram for deforestation/soil erosion,
(l) impact of droughts/floods,
(m) impact of introduction of new crop varieties,
(n) effect of male/female child birth,
(o) effect of husband/father's drinking,
(p) impact of project interventions, and
(q) problem/solution analysis

Flow diagrams cannot only indicate direction of flow but also the quantity (in relative or absolute terms). The interlinkages or flows may be weighed through fixed or free scores. Both flows and interlinkages can be represented by the lines of different thickness indicating relative significance. Primary interactions are represented by thick lines and secondary and tertiary interactions by progressively thinner lines. Dotted/dashed lines, colours can be used to differentiate between positive/negative impacts, internal/external factors and present/past/potential scenario, etc. A gender perspective can be brought out by using the above modification. It is possible to examine and perceive significant changes over time, whether related to one specific event (like project intervention) or incremental changes (due to community awareness). Both potential (the present and the future) and actual (then and now) changes can be visualised using different sets of lines and boxes Solutions of the problems can be indicated by different colour on network or flow diagrams (Figure 7 7).

Participation, materials and timing

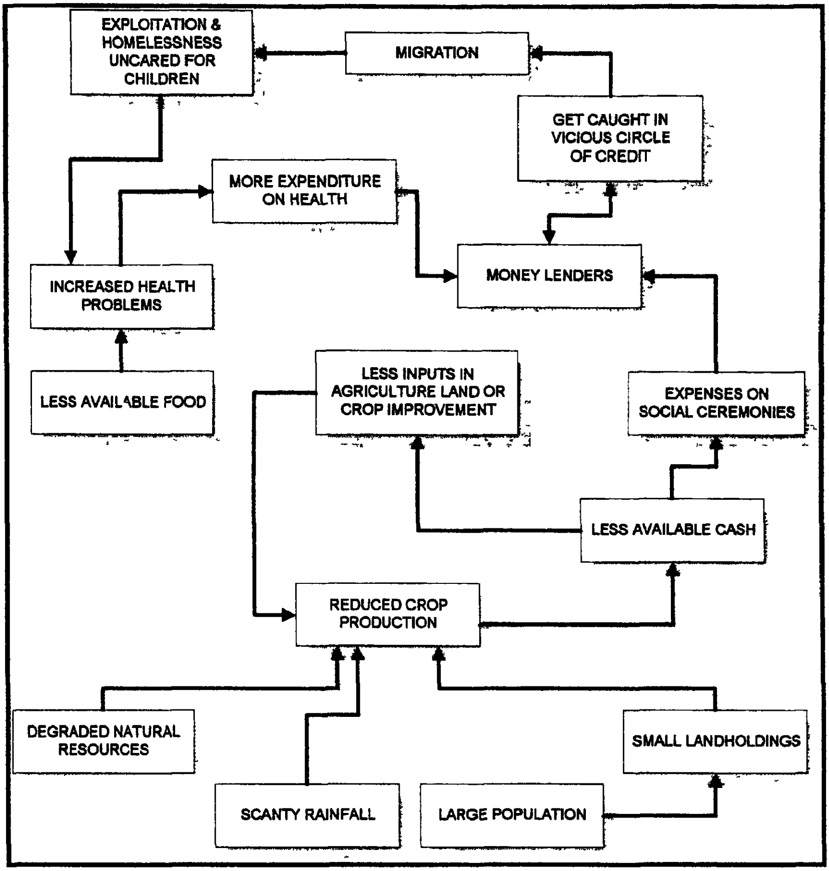
Individual issues can be worked out in households. Working with larger groups are indicated when the subjects under scrutiny are community issues, highly subjective and multifaceted Networking or flow diagrams are contraindicated in the initial stage of PRA, essentially due to its complexity Venn diagrams, transacts, timeline, pairwise ranking, scoring matrices, social and natural resource mapping can be followed by flow diagrams.

It is best to use a material which can be easily changed such as soft ground or chalk/pencil Objects/symbols may be used to depict elements in the boxes. Linkages or elements can be free or fix scored by putting numbers on the diagrams

Strengths and weaknesses

Complicated interlinkages and causes and effects could easily be represented by flow diagrams A quantum of information can be presented and complex analysis can be carried out. The interrelationships between external and internal factors can also be represented. Such diagrams can be constructed spontaneously from discussions without prior planning. To avoid confusion, facilitators should clarify the objectives, processes and issues to the participants in detail. It is important to limit the number of boxes and interlinkages and to avoid complicated diagrams A number of issues and elements have to be examined from numerous angles to achieve dynamism in the diagram Omissions in the network should be avoided The participation in such flow diagrams or networks may be reduced, if the facilitator takes up the job of completing the task To make this tool effective, participation should be ensured by the project implementing agency.

Figure 7.7 *Flow diagram (micro-watershed Dumpada, Jhabua) Flow diagram shows the dynamics of degraded natural resources leading to poverty, indebtedness and migration*


EXPLOITATION & HOMELESSNESS UNCARED FOR CHILDREN
MIGRATION
GET CAUGHT IN VICIOUS CIRCLE OF CREDIT
MORE EXPENDITURE ON HEALTH
MONEY LENDERS
INCREASED HEALTH PROBLEMS
LESS AVAILABLE FOOD
LESS INPUTS IN AGRICULTURE LAND OR CROP IMPROVEMENT
EXPENSES ON SOCIAL CEREMONIES
LESS AVAILABLE CASH
REDUCED CROP PRODUCTION
DEGRADED NATURAL RESOURCES
SMALL LANDHOLDINGS
SCANTY RAINFALL
LARGE POPULATION

Transacts

Transacts are observatory walks in a watershed Transacts help the facilitator to note several areas of interest and relevance which could have been missed Transacts help to find out salient features of·

(a) Physiographic features topography, hydrology, soil types, soil depth, soil fertility, soil erosion, slopes and contours, etc.
(b) Locally evolved techniques and management systems
(c) Crops and agriculture land use cropping practices and patterns, productivity, yields, etc
(d) Local vegetation fibre, fodder, fuelwood and multiple purpose vegetation, etc

Discussions with farmers and villagers can be pursued which are real, situation specific and visual Transacts help in getting information and insight into complex nature of the community and the nature which otherwise could not have been explained by traditional methods. Biases brought out by 'Rural Development Tourism' are taken care of In combination with other methods such as livelihood analysis (study of farming practices), mapping, etc , they can be used to assess, plan, monitor and evaluate resource management and development projects Local knowledge and experience supplemented with observations enhance the quality of the exercise Transacts can be done inside the village

Types of transacts

Transacts are essentially of two types, viz , village transacts and resource transacts

(a) *Village transacts* It is an observatory walk through the residential area of the village It has a greater focus on dwelling zone of the village Layouts of housing, drainage, drinking water, livestock, electricity, shops, schools, other community buildings, etc., could be ascertained by locating, assessing, mapping and analysing It gives greater insight into the social aspects of the village like castes, culture, traditions, customs, religion, health, etc. Habits, behaviours and intergroup interactions can be closely observed. Household activities and economic activities such as rural handicrafts, livestock management, etc , could be focussed. Discussions based on observations could provide interesting leads. A map of the village area with its layout could be compiled alongwith multifarious features

(b) *Resource transacts* These can be further divided into

(i) *Classical/straight transact* This is usually done by traversing the area in a fairly straight path, usually starting from an upper reach and moving downward towards the village and vice versa It provides understanding to project implementing agency or MDT members about agro-climatic, physiographic and ecological zones by analysing different cross-sections of the area Problems and opportunities, existing management systems relating to various resources could be understood in great details Observations are made at different locations of the watershed

(ii) *Zig-zag transact.* These transacts are done by the group walking in a zig-zag fashion covering a greater acreage of the area. Interesting observations can be made and the information collected is diagrammatically represented

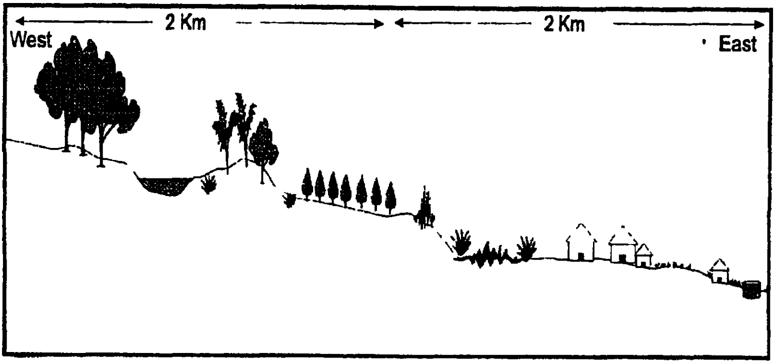
(iii) *Looping transact* The transact party may cover an area by adopting a looping tract from say point A to B (usually from a low point to high point) A variation in the form of several groups traversing several looping tracts may also be possible. In this multiple group transact, the groups meet at a pre-decided point to exchange and share information and discuss observations

(iv) *Nalla transacts* These transacts are performed by group (or groups) moving systematically up or down a watercourse Observations are taken on either side of *nalla* *Nalla* transacts throw light on several opportunities and ideas about micro-environment, water harvesting methods, etc. It highlights the diversity and variation existing at different locations in the watershed

(v) *Sweeping transacts·* Several groups 'comb' or traverse freely in pre-determined area or sections of the area It is important to exhaustively list plot-to-plot and field-to-field observations Sweeping transacts are usually taken as follow-up exercise of other transacts The informations and observations could form part of action plan

Transacts help in planning foi the structures and manpower for various treatment structures They help in learning about rural development, particularly about the complete interaction between men and environment, natural resources and their management, farm-based livelihood systems, vegetation and ecosystem, etc. (Figure 7.8).

Figure 7.8 *Village transact (micro-watershed Kakradhara, Jhabua)*



Land Use	Undulating forest land	Degraded forest land (with encroachment)	Village/habitation	Farm land
Soil	Hard mooram and rocky	Hard mooram and lateritic	Gravel	Black cotton soil
Vegetation	Plalash, bael, teak, coppices, ber, grasses	Neem and palash outcrop, grasses	Sitaphal and mango	Ber, sitaphal, khair, Ipomea
Crop	—	Kodo, kutki, kulthi	—	Maize, cotton, urad
Water source	Small nalla that dries up by November	—	Small seasonal pond and one hand pump	Dugwell
Problems	Soil erosion, water runoff, Illicit felling and theft	Soil erosion, degraded vegetation, encroachment	Poor water harvesting, fuel and fodder scarcity	Soil erosion, water scarcity, low production
Opportunities	Protection to assist natural regeneration, soil and water conservation	Silvipasture, water conservation, energy plantation	Education, health, credit, animal husbandry	Crop improvement, agronomic practices, supporting SWC, agroforestry, agrohorticulture

Strategies

Selection of a particular type of transact should be done after serious deliberation about the objectives Multiple looping or sweeping transacts are useful for preparation of action plan of a watershed Groups should ideally consist of 5 to 10 members from 2 to 4 project implementing agencies and other outsiders The course and traversed section should be carefully selected and identified An ideal group is a multidisciplinary one. Locals having expertise in resource management, crop management, livestock management, water harvesting, etc , should be clear about the objectives and the information to be collected.

When several groups are involved in the exercise, they can be asked to converge on a specific spot (say on the top of the hill) after traversing lower areas In this way, the quality of discussion, interaction and information is greatly enhanced Encourage the local participants to talk about various observations. The group should ideally consist of local participants whose plots or fields would be traversed Try to relate observations with local situations and take lead for other aspects Encourage discussions among the group members on vital observations and record the information in the format of map. Proper compiling of the findings should be taken up seriously.

Do not start the exercise in a sunny afternoon or late evening. Do not attempt transacts in a hap-hazard fashion and without planning Do not get overawed by the exercise—it is simple and fun Do not take anything for granted. Do not bore the group by irrelevant lectures and questions. Do not walk too fast, as a lot of information could be missed.

Strengths and weaknesses

Transact ensures to inculcate awareness and knowledge in the agency about the field realities before the action plan could be initiated. They can be used as an initial tool in PRA exercise. It provides baseline information on which fruitful discussions may follow. It reveals various aspects of the individual, community and nature in a very short span of time Seasonal variations may crop up, depending on the time of year when the transact is taken up. Outsider may decide the framework criteria on which the observations are based on Only a limited number of participants from the community can participate. In can be a very lengthy and time-consuming exercise depending upon the context.

8

Community Mobilisation and Participatory Institution-Building

Participatory development is a new socio-economic force aiming for sustained development at the village level. There is a close link between resources (land, water, forest, mineral, etc.) and community. Resources are used by the community with a great deal of interaction among individuals Allocation of resources, based on a community approach, rather than on an individualised one, adds an element of sustenance to the development process Participatory development is a non-conventional approach It requires and encompasses evolution of non-market, non-governmental people's organisation in the management of CPRs, changes in systems of property rights, methods of resource allocation etc.

Participation as a process relates to increasing adherence to a set of rules Adherence results in the emergence of an institution, which is a recurrent situation either self-policed or policed by some external authority (Schotter, 1981) As a process, participation has dynamics of conflicts, understanding, persuasion, prohibition, violation (of rules), etc The participatory process, depending upon the strength of social decision system, can be classified as conflict-resolving, problem-solving, welfare-oriented, equity-oriented or development-oriented (Plate 19)

Careful attention is required in formation of groups or institutions in micro-watershed villages The idea of forming village institutions does not create a new and conflicting power structure The planners and implementors should ensure fulfilment of following points:

(1) Have villagers understood the need for collective action? It should be based on concrete and objective criteria like RRAs and PRAs findings Is it that the group formation is taking place to get some benefits from the project? Is it that until and unless groups are formed they cannot get to the problem and solve them? Are the villagers motivated to form a group? What has been the perceived role of each beneficiary into the group?

(2) Do we have adequate and authentic information on prevailing local social systems? (Plate 20) Who participate in existing institutions? How they function and how the

Plate 19 *Participatory exercises bring all the factions of the community together on a common platform*

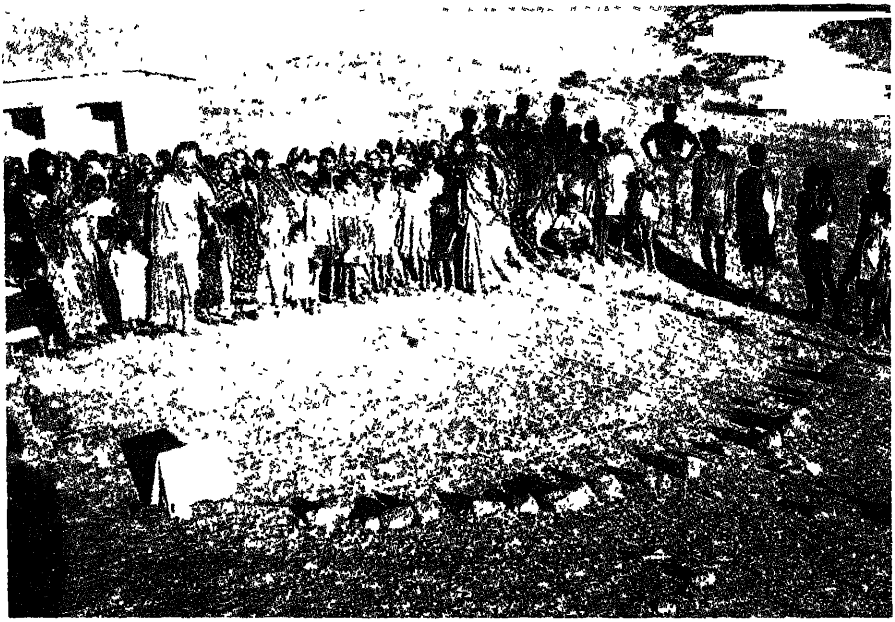


Plate 20 *Participating in social ceremonies can be an important tool towards community mobilisation*

decisions are arrived at? How has been the functioning of the group—satisfactory/unsatisfactory? Reasons? Who is the level of participation in existing institutions? What are the strengths and weaknesses? Who was involved in taking decisions for an activity that has/had come to the village? Were women, landless, minorities and backwards involved in the process of decision-making? Will the formation of a village institutions sharpen the factions in the village or sharpen the leadership struggle among individuals, households, social groups, etc.?

(3) Has it been ensured that the proposed village institution would allow for a wider participation among the relevant population including the women? Do the groups take the women into confidence? Are the women participating in the activities and in the decision-making? Are gender-based issues a priority goal or objective of the group?

(4) Is the proposed village institution-building on any existing institution? If so, then how can the restrengthening of the weaknesses of the existing groups be ascertained? If new institutions are built, then what are the differences from the existing institutions?

(5) Cooperation among villagers and decision-making capacity and management abilities of the beneficiaries should be tested and analysed through the implementation of small activities

(6) The project should start with small, single and simple organisations at hamlet or clan level. Activities and responsibilities to the people should only be given when the participation of poor and gender is assured, capacity-building in the members is ascertained and intended results are already achieved. Processes like meetings, accounts management, operations, etc , should be institutionalised

(7) Start with formal procedures (e g , regular meetings) but do not give formal titles like president/secretary etc New formally structured organisations should not be created unless there is an immediate pressing need to do so Ensure that all the members have been trained in cooperation, participation, accountability, etc. Rotation of the responsibilities should periodically take place Two-way communication among members should be encouraged

Sustainable development involves various aspects Sustainable development project should encompass appropriate technology, supportive policies, differences in ethics, changes in individual behaviour, local institution and participation, etc. Local institutions perform multiplicity of functions in a watershed area, such as

(1) Local institutions are important for mobilising resources and regulating their use with a view to maintain a long term base for productive activity

(2) Available resources can be put to their most efficient and sustainable use with location-specific knowledge, which is best generated and interpreted locally

(3) Monitoring changes can be quick and less costly Adaptive changes made in resource use gets accelerated by institutionalised local decision-making

(4) Community norms and consensus condition people's behaviour Preservation or institutional practices, which are environmentally sound, may require more than just individual incentives and persuasion Community wisdom is more practical and sustainable

(5) In the absence of local institutions, all conflicts are dealt with at higher levels, yielding slower and often less appropriate outcomes Local institutions help in resolution of most of the local conflicts It becomes a mechanism in conflict resolution

(6) Local institutions encourage people to take a long term view by creating common expectations and a basis for cooperation that goes beyond individual interests. Local institutions carry a legitimacy, so people comply without inducements and sanctions Local institutions have their own rules and pattern of management. They should be appropriate to the resource to be developed and maintained and they should impose sanctions which they can enforce in their own areas of operation. Such institutions must also have access to and control of resources to meet urgent needs and future options.

Local institutions can produce practices that do not favour sustainability Factionalism within the institution or among the groups may induce them to exploit local resources to their short-term advantages at the loss and peril of others Local institutions regulating natural resources and common property resources are easiest to breakdown This may further vitiate environment for existing institutions and probable ones

Local institutions by and large depend on, and are reinforced by, existing structures of authority If tradition and authority uphold conservation or preservation, then it is accepted (Wade, 1987). The management and ownership of CPRs in Rajasthan was in the hands of feudal class, a focal point of traditional authority (Jodha, 1985) Informal protection groups/Van Panchayats have been traditional source of authority in Madhya Pradesh and hence could manage forests effectively Panchayats, all over India have been a centre of traditional authority for centuries thereby enabling to effectively direct and lead the community and to manage and administer resources with authority (Gula, 1985) Individuals cooperate and follow the rules set down by the community only if the use of resources to be managed satisfies some of their very significantly felt-needs.

The umbrella of local institutions consist of institutions at three tiers

(a) *Group level* (Self-identified set of persons with some common interests) It may be persons in a small residential area like a neighbourhood or an occupational, age, gender, ethnic or other grouping User groups, self-help groups, etc , at micro-watershed level are the lowest tier of local institutions

(b) *Community level* (Relatively self-contained socio-economic residential unit). Watershed Development Committee and Watershed Association are second tier of local institutions in watershed areas.

(c) *Locality level·* (Local institutions having social and economic relations) It may be extended to block (sub-district) levels Project implementing agency (PIA) or multidisciplinary team (MDT) in watershed come in the third tier There is more prevalence of face-to-face interpersonal relationship which are often more frequent, intense and meaningful than within locality level (block level) institutions.

The fact that people know each other (especially in group level and community level institutions), creates opportunities for collective and mutual assistance for mobilising and managing resources on a self-directed and self-sustaining basis People feel more mutual rapport and sense of obligation at these levels Since, these institutions exist as social entities, decisions and activities are based on consensus which grow out of discussion and mutual understanding The individual and household level institutions are the smallest units of decision-making and activity Decisions taken by them regarding sustainability of watershed project and sustainable utilisation of natural resources are not likely to be very effective or long lasting Such decisions should be meshed with decisions by other individuals and households Local institutions provide a basis for collective action for building consensus, for undertaking coordination and management responsibilities, for collecting, analysing and evaluating information energised by a degree of interpersonal solidarity.

There are many types of institutions, some of which are also organisations (e.g , Gram Panchayats) and others which are not (e.g , money). An institution is a complex of norms and behaviour that persist over time by serving some socially valued purposes, while an organisation is a structure of recognised and accepted roles (Uphoff, 1986) Institutions can be organisations and *vice versa*. Marriage is an institution but not an organisation, while family is both. Local institutions, in the present context, are meant by institutions with organisational basis. The vitality of institutions at different levels depend to a large extent on the degree to which they meet the expectations of the members whose resource contributions (money or kind) are needed to keep them operating. Many institutions are vulnerable to the withdrawal of support by members Institutions which fail to mobilise their resources due to the loss of support, loose their sustainability and start depending on outside resources

Role of local institutions in sustainability, productivity and equity

The three main objectives of integrated watershed development project are sustainability, productivity and equity. It has been amply emphasised now that to ensure sustainability, especially where there is a majority of BPL families, women or landless, assistance and support to emergence and establishment of local institutions is crucial (see Chart 8 1)

Chart 8.1 *Criteria of sustainability*

(i) Marked and sustained improvement in productivity of fields of all farmers (especially small and marginal)

(ii) Improvement in groundwater recharge

(iii) Maintenance of structures and vegetative barriers.

(iv) Continuous improvement in the regeneration of all lands in watershed areas, especially in private fallow and community degraded lands

(v) Increased investment in protective irrigation through water harvesting structures

(vi) Marked improvement in productivity and quantum of fodder production from private and community wasteland

(vii) Marked improvement in resilience of crops to long and frequent dry spells

(viii) Stable market mechanisms for the crop produce

(ix) Development and perpetuation of income-generating allied activities like fisheries, sericulture apiculture, dairying, etc

(x) Adequate acquisition of skills to construct and maintain all kind of soil and water conservation structures

(xi) Ability of farmers to contribute resources for maintenance, management and repair of the SWC structures in watershed

(xii) Ability of institutions to resolve conflicts among various groups in the watershed, and to respond to the needs of groups whose interests are affected by watershed treatment (like landless or herdsmen whose grazing rights are curtailed due to social fencing on fodder land)

(xiii) Gradual extension of effective and efficient management by institutions over all the land in watershed (private/revenue/forest or upper/transition/lower areas)

(xiv) WA and WDC take over the control of project implementation and management

There could never be single panacea for all watershed areas. WA may be a useful institution but it can never have uniformal and universal application to achieve sustainability, productivity and equity in the process of development Though, Jhabua has homogeneous structure of the society, even then class, gender, landholding, etc., make them heterogeneous In other states, the heterogeneity is more extensive In such situations, large institutions carrying numerous factions and heterogeneous groups may face problems in proper functioning The vocal and powerful in such groups will dominate to consolidate their own interests Such institutions cannot form an institutional base for sustained management of the micro-watershed In Jhabua, following concomitant problems which further curtailed the effectiveness of such large institutions were found

(i) Farmers with lands within the watershed but living outside
(ii) Farmers with lands within the watershed but migrate for 3-6 months every year to nearby states (Gujarat, Rajasthan, Maharashtra) in search of employment
(iii) Farmers with lands outside the watershed but living within.
(iv) Landless or marginal farmers with unproductive lands and who harvested the resources of the watershed to which they had access
(v) Watershed beneficiaries with diametrically opposite political ideologies.
(vi) Beneficiaries who traditionally used the common land,
(vii) Villagers residing in distant and remote houses on hillocks or *phalias* (hamlets)(distance barrier)

Due to above constraints, more than one WA and WDC were formed in some micro-watersheds It also becomes necessary to restrengthen and revitalise smaller, compact and high affinity SHGs and UGs This was achieved in Jhabua by restrengthening *Baira-ni-Kuladi* (women's credit groups), *Jal Samiti* (water user groups), *Gram Van Samiti* (village forest committees), CPR user groups, *Kishori Balika Samuh* (groups of adolescent girls), etc The heterogeneity in such groups is less, so they act as cementing agent for 'fractured' WAs In certain other cases, ancillary WDCs formulated, initially consisting of beneficiaries from most susceptible, vulnerable and erosion-prone land holdings. Gradually, with the progress of implementation other members were roped in Such WDCs were more representative and effective Another approach, which proved beneficial, was to cultivate WDC as a central focal activity or strong feature of the watershed village For villages on milk-route, dairy society became the main focal group for villages with large degraded forests, VFC were the main focal groups and villages with active panchayats, Gram Panchayats were the main for focal groups Other members were gradually and with process of time opted into such focal groups to formulate full-fledged WDC Special compensatory schemes or programmes may be highlighted or pursued with vigour for 'have nots', for example *gramodhyog vikas* (village-industry development) for landless, *Baira-ni-Kuladi* (women credit groups/banks) for women, agro-horticulture development for marginal farmers, etc., give such group special status Such compensatory programmes bring every group to a same status in WDC. Positive discrimination like asking for less contributions in *gramkosh* (village fund) from SCs, STs, women, landless beneficiaries, or more representation in WDC (representation more than their proportionate population) has also proved effective in making WDC or WA more participatory

Thus, PIAs cannot insist that there should be one WA or WDC in a micro-watershed The process through which a WA or WDC emerges will differ in each watershed Therefore, only a group of properly selected and elected 12-15 members WDC would be able to achieve the objective of regenerating and managing the watershed resources and of ensuring the effective and sustained participation of all the households in planning and implementing treatment activities and in sharing the benefits equitably. The traditional community management systems of the village should be respected and integrated in the watershed organisational framework.

Institutional arrangements in watershed

WAC (Watershed Advisory Committee)

WAC is an advisory body for watershed development programmes in extensive areas. The traditional institutional arrangement for implementation through government departments is supplemented by involvement of NGOs, semi-governmental institutions and private enterprises The district collector has been appointed as the mission leader for Rajiv Gandhi Mission on Watershed Development The District Rural Development Agency (DRDA) is made responsible for implementation of national guidelines at the district level with executive director/CEO (ZP) acting as project director in RGMWD The DRDAs approve the watershed development plans (WDP) and the selection of PIAs The DRDAs receive funds directly from the Government of India and the State Government under Employment Assurance Scheme (EAS), Drought Prone-Area Programme (DPAP), Desert Development programme (DDP), Integrated Wasteland Development Programme (IWDP), etc , for implementing the watershed development programmes under national guidelines Funds for the approved watershed development projects are released by DRDAs to the WDC Besides, DRDAs exercise necessary administrative and financial controls over the PIA, MDT, WDC in terms of release of funds, inspection of works, super-check on the maintenance of accounts, enquiries into complaints, etc The DRDAs lay down formats/norms and guidelines for maintenance of accounts, exposure visits, capacity-building, community mobilisation, treatment works, etc The Zilla Panchayat supports and supervises DRDAs in their functioning and periodically monitors the quantitative and qualitative performance and progress In Madhya Pradesh, DRDAs are provided with an assistant engineer (geohydrology) on deputation to work as assistant project officer (watershed) in DRDA Similarly, 10 range-level officials are posted in DRDA on deputation from forest department Most of them have been posted as project coordinators in governmental PIAs The collector is authorised to constitute a Watershed Advisory Committee (WAC) at the district level under the chairmanship of Zilla Panchayat chairman/president The WAC comprises of collector, CEO(ZP)/ED(DRDA), all MLAs, all project officers (PIAs), one or two members from the relevant research and training institutions in the district The WAC must meet regularly and advise and assist the DRDA regarding the eligibility of PIAs, members of MDT, various aspects of WDP, training, community mobilisation and such other items as may be assigned to it by the DRDA

PIA (Project Implementing Agency)

As it is desired in the national guidelines, voluntary agencies and other institutions such as universities, agricultural research and training institutes, corporations, cooperatives, banks, public and private commercial organisations, and panchayati raj institutions (PRIs) may be allotted group of selected villages for planning, coordinating, supervising and implementing WDP. The role of the PIA is to coordinate with the Gram Panchayats to pass necessary resolution to make public contributions, conduct PRA exercises, to prepare WDP for each watershed, form and register WDC in DRDA, community organisation and training for the village communities, provide technical guidance and supervision in implementation, inspect and authenticate project accounts, validate and build upon indigenous technical knowledge, monitor and review the overall project implementation and set up institutional arrangements for post- project operations and maintenance and further development of the assets created during the period Only class I officials should be appointed as project officers of the PIA The PIAs can be given the assistance as mentioned earlier The PIAs should have an MDT comprising block (sub-district) level officials of relevant departments. Only open-minded, sensitive, zealous and honest officials should be made a part of MDT. Block-level officials from forest, agriculture, soil conservation, irrigation, rural engineering services, fisheries, veterinary, horticulture, and geohydrology departments may be included in MDT/WDT under PIA Each MDT handles one milli-watershed comprising 8-12 micro-watershed with an area of 4500 to 6000 hectares Each MDT has 6-10 members The MDT works for the WDP in the selected villages The VA/NGOs constitute MDT with either government officials as PIA members or experts of their own on forestry, agriculture, animal husbandry and social sciences The PIAs are provided with one full-time and exclusive community organiser (with MSW qualification and two years field experience) and two project assistants (with degrees in commerce or agriculture/civil engineering) To retain merit, these contractual appointments can be made by district level selection team under the guidance of WAC

WA (Watershed Association)

Where a watershed is co-terminus with a Gram Panchayat, the concerned Gram Sabha is designated as the WA Where a watershed comprises of area coming under the jurisdiction of more than one panchayat, members of the community directly or indirectly dependent upon the watershed area are organised into WA Thus, all the adult members (with age above than 18 years) are members of WA There is a provision in National Guidelines to register all such WA under the Registration of Societies Act But, in Madhya Pradesh, this proves has been done away with Instead, more practically, PIAs and WDCs are registered under Registration of Societies Act, which the State Government by a special legislation, has conferred such powers on DRDAs The WAs meet, at least, four times a year to evolve/improve the WDP, monitor and review its progress, approve the statements of accounts, formation of user groups/self-help groups, resolve differences or disputes among different user groups and self-help groups, approve the arrangements for the collection of public/voluntary donations and contributions from the community and individual members, lay down procedures for the operation and maintenance of assets created, approve the activities that can be taken up with money available in watershed development fund, nominate members of the WDC from amongst the user groups/self-help groups by system of rotation and take disciplinary action of removal of member from WDC The WA elects its own president, who is generally different from the office bearers of the WDC

WDC (Watershed Development Committee)

Subject to the overall supervision and control of the WA, the day-to-day activities of the WDP is carried out by WDC. The WDC normally consists of 10-12 members, who are nominated by the WA from amongst the user groups (4-5), self-help groups (3-4), Gram Panchayat (2-3) and a member of MDT While making nominations, adequate representation of women, SCs, STs, landless, etc., is ensured As in Jhabua, 50% posts of WDC members for women may be reserved. The WDC elects its chairman from amongst its members and it performs such functions as are assigned to it by the WA In Jhabua, the chairman of associated JFM committee is ex-officio member in WDC. Similarly, 50% seats for chairman, WDC are reserved for women The WDC performs the functions of coordination and liaisoning with the WA, Gram Panchayat, the MDT, the PIA and the DRDA/ZP Each WDC has a selected watershed secretary He is a full-time, paid employee of WA/WDC He is preferably a graduate from the same village He works under the direct supervision of the chairman of the WDC and is responsible for convening meetings of the WA and WDC and for carrying out all their decisions He is responsible for maintaining all the accounts of WA and WDC He helps UG/SHGs to maintain their accounts He is assisted by two volunteers in each micro-watershed—*Bhayya* (male volunteer) and *Bonn* (female volunteer) as in Jhabua WA in consultation with PIA decides about the secretary and the volunteers

The basic functions of institutions in watershed area should be to.

1 offer a forum to interact with external agencies interested in supporting developmental works,
2 implement various components of the watershed programme,
3 disseminate the implications of integrated watershed management to the people;
4 mobilise direct and indirect contributions (money, labour, material) from the beneficiaries to form a community fund/pool and administer the same in maintaining the community assets created under the programme,
5 promote and support creation of other functional groups (e g , agro-processing groups, vegetable producers' union, nursery raising groups),
6 resolve conflicts locally in a democratic fashion, and
7 formulate and implement collective decision on matters related to watershed management etc

Community mobilisation in mission mode

The interventions described are drawn mainly from Jhabua experience, where both the government and NGOs are operational partners The basic philosophy of Jhabua model of integrated watershed development has been discussed in Chapter 1 The Joint Forestry Management/Informal Protection Groups were the foundation on which the whole apparatus of watershed management was launched *Baira-ni-Kuladi* (women's credit and thrift groups) were the initial self-help groups in all the micro-watersheds The WDP included exhaustive interventions in soil and water conservation treatment and biomass production along with introduction and strengthening of agricultural techniques, horticulture, fisheries, dairy, mushroom cultivation, agro-forestry, rural industries Education, health, housing, sanitation, and non-conventional and energy systems were emphasised, modernised and improved Thus, the approach was to create a model of integrated watershed development in which all the paradigms of development like watershed, agriculture, horticulture, social forestry, dairy development, rural housing, rural technologies, rural credit systems, health, education, women and child development, literacy and other rural development and tribal welfare/development concepts were practically interwoven These interventions did not follow a pre-conceived pattern. To achieve these objectives, watershed development programme from October 1994 was started under the Rajiv Gandhi Mission on Watershed Development. The basic approach was multidisciplinary, missionary and holistic with the active participation of the community The various tasks performed by DRDA were·

1. selection of sub-watersheds, milli-watersheds, micro-watersheds;
2. selection of PIA and MDT;
3. formation of WAC and technical committee,
4. registration of PIA;
5 capacity-building of PIAs, MDT and WDC,
6 campaign for awareness building and community mobilisation,
7 institution-building;
8. preparation of project action plans and sanction of WDP,
9 streamlining accounts and organisational set up,
10 formulating monitoring and evaluation formats, and
11 implementation, monitoring and evaluation

Means of community mobilisation

The most observable situations in which participation emerges is the existence of common problems, which forces the people to come together to take decisions regarding common action. Threat of soil erosion to the agricultural plots, paucity of fodder and fuelwood, scarcity of water for drinking and domestic use, loss of vegetation, etc , are the commonly perceived problems which resulted in high level of community participation in watershed management programme in Jhabua Participation may emerge either as a consequence of the conscious, collective action of rational economic agents (Commons, 1961) or evolving organically out of individual behaviour (Menger, 1983) Self-enforced societal rules such as stall-feeding or social fencing by institutions regulate individual behaviour and social responsibility with respect to resources The participatory development process, based on the creation of links between CPRs and PPRs in the watershed area, is found to be stable and sustainable Apparently, under-employed could be mobilised easily for participation Participatory institutions own up added organisational responsibility of maintenance and repairs in watershed They are better equipped to bridge the communication gap between the government and the people.

Community participation is essential for successful implementation as well as for the maintenance of community assets created under the project Community mobilisation could also be viewed as an important mechanism through which the responsibilities of common property resources management could be transferred back effectively to the people, so that, more productive, sustainable and equitable development is possible The level of envisaged motivation and mobilisation could be possible by using various social processes:

(1) *Awareness*:
- use of promotional material,
- sharing information,
- attending topic-specific workshops,
- focussed awareness creation, and
- exposure visits to other projects

(2) *Involvement*.
- participating in the planning process (PRA),
- giving opinions, ideas and alternatives,
- raising doubts, problems and options, and
- promising contribution and involvement.

(3) *Learning*·
- improvement of knowledge and skills through training,
- application of innovations, and
- developing a sense of self-appraisal

(4) *Organising*·
- attending community meetings,
- resolving conflicts,
- developing attitude to work or decide with consensus,
- establishing group norms and group dynamism,
- developing a feeling of solidarity, and
- arriving at group decisions

Numerous means have been used in the past for promoting people's participation and community mobilisation (Plate 21 a, b) Some of the commonly used methods are as follows

1. Entry point activity
2. exposure visits
3 *Kalajathas* (cultural troupes)
4 RRA and PRA techniques
5 Land literacy campaign
6. Village meetings
7. Formation of UGs/SHGs
8. Audio-visual methods

Measurement of participation is possible only at the institutional level, through the number of activities agreed upon or the number or rules to which a social agreement has been reached. Membership of the institution or the number of persons attending the community meetings may also be utilised for measuring participation Intertemporal variations in such measurements may give idea about the dynamism of the participatory process A participation index could easily be evolved using CPR, PPR and development information on households with different degrees of access to CPRs The size of the participating cluster *vis-a-vis* the total number of households in a watershed can be considered as the 'index of participation'

Plate 21 (a, b) *Kalajathas are effective means of spreading the spirit of watershed management and involvement of the community*

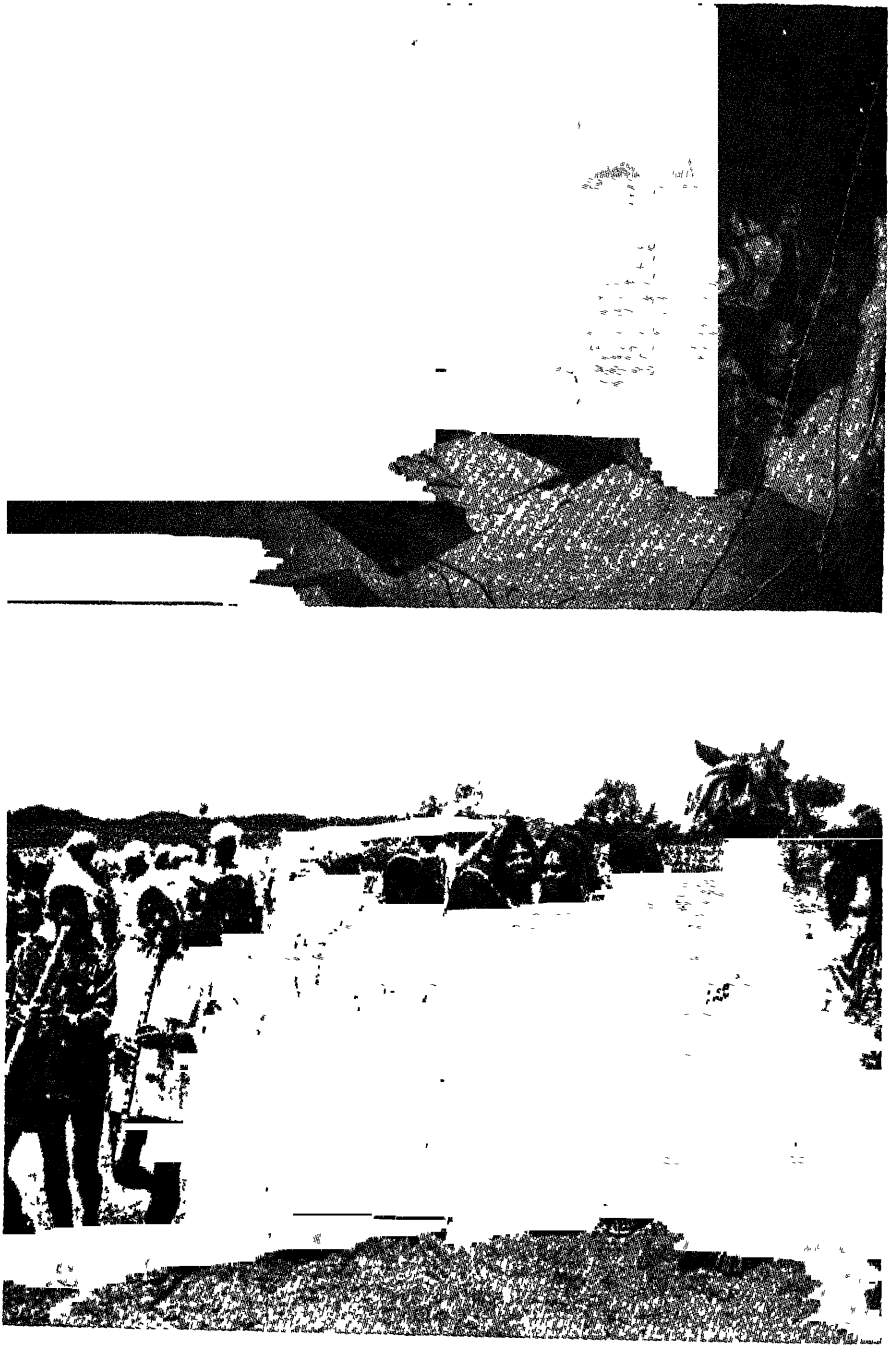


Chart 8.2 *Recommended qualities for head of the village institutions in watershed areas*

(1) Leadership qualities: Democrat, acceptance by people, wide coverage in the field, everybody knows him/her, can lead a group to some office, can conduct meetings, etc
(2) Honesty/integrity Villagers think that he/she is an honest and upright person, can keep money of others safely etc
(3) Innovator Practice new ideas like cropping pattern, SWC structures, kitchen garden in open area around the houses, maintaining records of farm, etc
(4) Literacy He/she has some formal education
(5) Time availability He/she can work for the project and he/she has the willingness to work He/she can find time for motivation and meetings
(6) Initiative He/she can take initiative on his/her own
(7) Past responsibilities undertaken He/she has successfully accomplished past responsibilities
(8) Exposure to outside world
(9) Eagerness to learn
(10) Skills He/she has sufficient managerial, organising, administrative and communication skills
(11) Motivation factors Service, commitment, vision/clarity about the project
(12) Attitudes
(13) Conduct and appearance

Identification and realisation of commonalities, shedding individualised value and belief systems, identification of the greatest common good for the greatest number of people, foreseeing the evils of atomisation of commons, etc., require mass appeal, demonstration and intervention Leadership focusses the village economics and ecology with common problems and assists in the community mobilisation

Local institutions' effectiveness in natural resource management

Participatory or self-help institutions are more viable and effective in watershed areas Generally, around 50% of the watershed community, that is, those villagers who are directly or indirectly dependent on the watershed are enrolled as members of at least one self-help group Separate self-help groups (SHGs) are organised for women, scheduled castes/tribes, agricultural labourers, shepherds, etc SHGs should meet regularly at least once in a month and take all their decisions by common consensus amongst the members The size of the SHG should be of about 10-20 members to enable effective individual participation in the group deliberations and working The group may not necessarily be registered The SHGs so created should have homogeneity regarding age, class, occupation, residence, etc , in the group They should have an experience of about 6 months before effectively taking up large-scale activity There should be culture of democratic working in the group and they should be well versed with maintenance of proper accounts/records The project implementing agency should be convinced that the group has not come into existence only for the sake of participation in the project and availing benefits thereunder There should be a genuine need to help each other and work together among the members The SHGs should be restrengthened to take up active role in planning and implementation of WDP Self-help groups of landless labourers, rural artisans, fishermen, etc., have been instrumental in initiating community mobilisation and participation in watershed activities in Jhabua.

User groups have been more effective as they are related to the benefit sharing in the watershed areas. User groups should be groups of 10-20 homogeneous and common resource users in the village. Nearly 50% of the families in the watershed community are represented in at least one user group. About 80% of the watershed development activities should be carried out through the concerned user groups. If the user groups are strong, the productivity, sustainability and equity concerns in the watershed areas are taken care of. They should meet regularly, at least once in a month, and take all decisions through common consensus amongst the members. The members should be able to give voluntary donations/contributions for the related project activity in terms of cash, kind or labour as per the prescribed norms. The user groups like water utilisation committee, dairy groups, farmer groups, etc., may play pivotal role in not only implementing watershed activities in an integrated fashion but also can actually take over the operations, and maintenance of the completed community works or activities on common property resources and personal property resources

The characteristics of the natural resource in question, as well as of the persons who would use it, condition the feasibility of managing it beneficially through local institutions over time Local institutions are more likely to be successful in natural resource management, when the resource is known and predictable rather than shifting and variable and where the users themselves are unidentifiable groups or community with its own authority structure In watershed areas in Jhabua, irrigation of water from water harvesting structures and fodder and fuelwood from socially fenced degraded forest patches are found to be most predictable and assessable resource Institutional arrangements are more successful where the users are a socially cohesive group Even in as predictable resource system as irrigation, there may be less solidarity among farmers in large systems This may happen due to difference in size of land holdings, position of the fields (upstream/downstream), etc. The most irregular pattern was found in grassland management by migratory population In such a condition, local institutions may find it difficult to control access and regular resource use User management is another option, i.e., management by individuals who use the resource within certain cultural and social norms that are not enforced by any formal authority (Roe and Fortmann, 1982) Such institutions are based on shared values and expectations

The potential of local institutions for natural resource management can be improved by investing in gathering information on resource and making it available to local people Formulation of user groups, in the long run is a good investment for promoting local resource management Social technological interventions like deployment of catalysts, like community organisers or social organisers to overcome barriers to resource, user cooperation may prove vital. The nature and distribution of costs and benefits from local management of natural resources will also affect the feasibility of local institutions taking responsibility Cost and benefits from/on natural resources management can vary in.

(1) *Space*· costs/benefits accrued locally rather than remotely
(2) *Time* costs/benefits accrued immediately or in short time frame rather than after a long time
(3) *Tangibility*· cost/benefits are quite evident rather than hard to identify

(4) *Distribution* benefits accrued to the same persons who bear the cost of management rather than to those who don't.

Quite evidently, local people take responsibility for natural resource management where the benefit accrue more quickly, locally, visibly and to those who bear the cost. The relative magnitude of costs and benefits from natural resource management are important, but these are often hard to measure and compare Management will be more sustainable where benefits can be made more definite and immediate, or conversely, where costs are more ambiguous and deferred The first step, in establishing participatory development, should be to determine the unit for decision-making and activity above the household, whether a group, a community, a locality or some larger unit. This should not be decided unilaterally but on the basis of discussions with persons in the area concerned Generally, it is most effective to start by talking with people in a household, then in small groups of households The purpose of the discussions is to find a match between perceived difficulties (natural resource, health, education, agriculture, etc), and areas or arenas of action to resolve them The process of mobilising local participation for sustainable development initiatives depends very much on a consultative, problem-solving approach Approaches like participatory or rapid rural appraisal carried out with communities and groups are a good starting point But by themselves, such approaches are not sufficient Community mobilisation in watershed programme in Jhabua is based on the assumption that rural people have more to contribute to the development process than just their money or labour power They have ideas, management skills, technical insights, organisational capabilities that are needed for development Hence, they should not be regarded as 'beneficiaries' or 'target groups', but should be treated as 'partners'. Due to the problem solving approach, systematic information can be gathered which will help to eliminate the problems, to clarify their sources, their magnitudes, their trends, the distribution of their effects etc Problems should be given priorities according to how significant they are (how urgent, how broad their impact, how great the costs they impose) and how amenable to solutions they may be. Trivial and intractable problems obviously get lowest ranking, and major, easily solvable ones deserve most attention and effort Trade-offs between significance and tractability can best be made by discussions leading to consensus After establishing priority problems, strategies for dealing with them need to be worked out by discussion, taking all views and experiences into account A plan of action is needed to carry out the strategy, specifying who will do what, when, how, etc Periodic evaluations should take care of local organisations, groups or communities Successes are achieved by eliciting widespread participation in the problem identification and analysis, as well as in the planning and implementation of solutions Once groups, communities or localities have made serious efforts to solve priority problems by their own initiative and with their own resources, they are in a stronger position to get assistance from higher levels to deal with problems that cannot be redressed locally The process of mobilisation starts with self-help efforts but engages higher level resources to the extent that local efforts are not effective It is not recommended to create local institutions for their own sake The PIA must be careful that they promote or support only organisations that are likely to serve real needs, otherwise the chances of these becoming institutionalised and self-sustaining are slim Sustainable institutions, ones which meet people's needs and expectations, are important and vital for sustainable development Common conflict situations observed in watershed organisational set up are depicted in the following Chart 8 3

Chart 8.3 *Common conflict situations in watershed organisational set up*

(1) Due to lack of communication between DRDA and PIA, PIA and WDC, WDC and WA, WDC and secretary or volunteers, WDC and SHGs and UGs
(2) Among SHGs, UGs, WDC, PIA, MDT, DRDA and WAC due to illdefined roles, responsibilities and accountabilities
(3) Within WA on CPR management, distribution of usufruct rights from JFM areas
(4) Within WA due to difference in opinion regarding removal of encroachments.
(5) Within WA on selection of sites for SWC measures, plantations, grasslands, etc
(6) Within WA due to heterogeneity of the composition like caste, class religion, clan, etc
(7) Within WA between land owners and landless due to differential expenditures on land-based activities and non-farm activities
(8) Within WA on sharing of benefits from watershed management like moisture, water, agricultural production, fodder, fuelwood, NTFP, small timber, etc
(9) Within WA due to apathy in certain sections of the community like, women, landless labourers, scheduled castes and tribes, migrants, etc
(10) Within WA or within WDC due to differences in opinion while formulating action plan or deviations from action plan
(11) Between WA and adjoining villages due to contradictions in village boundaries
(12) Between WA/WDC and adjoining villages as adjacent villagers feel that the programme should be implmented in their village as well and that their resources are getting depleted due to conservation and protection of CPRs on which they had user's rights and their CPRs (like water reservoirs) are getting depleted by manipulation in watershed villages (like *nalla* bunding)
(13) Between WA and WDC arising, when WA feels that their aspirations and needs are not fulfilled by WDC
(14) Between WA and WDC due to imposition of punitive actions by WDC on violators from within the community
(15) Within WA, within WDC or between WDC and Gram Panchayats due to personality and ego clashes
(16) Between WDC and VFC on sharing of fuel, fodder, forage, small timber, NTFP, etc , from mutually protected degraded forests
(17) Within WDC on selection of secretary, volunteers, etc
(18) Between WDC and Gram Panchayats based on struggle for supremacy and domination on development of the area
(19) Between WDC and PIA arising from interferences and controls of PIA for financial discipline
(20) Within MDT due to differences of opinion and perceptions among officials from different departments regarding different aspects of watershed development
(21) Between PIA and forest department due to stringent forest laws preventing PIA to enter the forest areas and execute the action plan
(22) Between PIA and other departments, when officials from departments like revenue, forest, rural development, agriculture, etc , may feel PIAs intervention in the area as interferences in their domain
(23) Between PIA and DRDA due to delays in submission of reports, violation of directives, audits for financial control, etc
(24) Between DRDA and Zilla Panchayat/people's representatives as people's representatives feel that money should have been spent by DRDA on construction of stop dams roads, culverts, school buildings, etc , rather than spending it on watershed management

Integration of people along with other agents of decision-making, namely, government, technology, social and cultural institutions can lead to a sustainable and holistic development of the individual, community and the ecology in a watershed

WDP (Watershed Development Plan)

Development of watershed is an activity which is carried out for the following purposes:

(i) improvement of the living standards and conditions of the population,
(ii) control of soil erosion and soil degradation by comprehensive soil and water conservation,
(iii) to satisfy the economic requirements and the security of the population in a watershed,
(iv) protection of infrastructure and public investments,
(v) establishment of the ecological balance between man and his environment,
(vi) production of sustained increased yields through better crop, animal husbandry and forestry practices, and
(vii) provision of adequate marketing facilities, etc

Planning for watershed development plan has to be carried out in close cooperation between the specialists and experts in the various disciplines and the community The problems of a watershed area are usually so tangled and complex that it is hard to know where to begin It should be borne in mind during preparation of WDP that one aspect of the development of a catchment area depends on what is to be done elsewhere They are an important means for obtaining administrative approval for funds to be spent and work to be done The better the planning which is done for WDP, the more reliable will be the information on costs and results Most watersheds require a variety of actions to be taken by many people, both private persons and officials of the government It also serves as a means for making clear what can be done by the government and what must be done by the private land users A carefully prepared plan will also indicate the timetable for development Entry point activity may be taken up while initiating watershed development in the area (indicative list shown in Table 8 1)

There are many kinds of watershed plans, each having a special purpose in general, the purpose which the plan is to serve determines the nature of the plan For some purposes extremely detailed planning is required, and for other purposes reconnaissance planning is quite sufficient Planning in WDP relates to the making of a decision as to what should be done, and designing is related to deciding how to do it The term 'design' is used to mean the planning of detailed features of the operating programme 'Work Plan' in WDP includes aspects of watershed work other than structural designs

Following strategies are used frequently in preparation of WDP

(i) Various and multiple PRA techniques
(ii) Available records (like toposheets, revenue maps, census reports, etc)
(iii) Aerial or remote-sensing imageries
(iv) Socio-economic surveys
(v) Land-literacy campaign

Various watershed characteristics and sources of obtaining information regarding them are given in Table 8 2

Table 8.1 *Illustrative list of entry-point activities*

1	Handpump
2	Irrigation canal
3	Repair of school building, wells, etc
4	*Ghaat* construction on village tank
5	Approach road
6	Culvert on approach road
7	Cattleshed
8	Television
9	Diesel pump/spray pumps/agricultural implements
10	Thrasher
11	Musical instruments
12	Nadep pits/biogas
13	Development of *Devasthan/Devasthali*
14	Well for drinking water
15	Furniture for school
16	Community-assisted village tanks
17	Community bathrooms/toilets
18	Village electrification
19	Repair of piped water supply
20	Village drainage system
21	Repair of lift irrigation schemes
22	Storage facility for crop produce
23	Repair of religious places

(a) *Watershed area treatment plan* It covers a catchment area which is to be the scene of the programme of work. A comprehensive plan indicates all of the various things to be done to achieve an improvement in the behaviour of the stream that drains the area They would be detailed and precise They should indicate by means of maps, tables, charts and text, exactly what is to be done, where it is to be done, by whom, how and when Agronomic measures for agricultural lands, erosion control structures on non-agricultural areas, water conservation and harvesting, groundwater management, community plantations, agro-forestry, etc , should be included in the treatment strategy. The designs, locations and cost estimates of these structures should be included

(b) *Community development plan* It is not very difficult to plan and take action on the problems of a forested watershed, where the land is all owned and controlled by the state and private persons neither live there nor have any rights to the use of the land When private persons have rights to the use of watershed lands, their private interests, as well as the public interests must always be taken into account The objective of community development plan is to promote self-help on problems of land and water use and on other problems The area for community development planning may be different from area under treatment plan The planning of community development is primarily a means for organising the action of private persons to make their contributions to the improvement of their

Table 8.2 *Important watershed characteristics and source and means to obtain information of WDP (illustrative)*

	Characteristics	*Required for*	*Parameters and indices*	*Source and means to obtain*
1	Size	Average precipitation, runoff and sedimentation (rate and volume), production potential, workload	Standard area unit	Topo-maps, satellite images
2	Shape	Runoff and sedimentation (rate and volume), operational schedules and conveniences	(a) Geometric form (b) Shape Index (c) Compactness coefficient (d) Farm factor	From topo-maps, aerial photos, satellite images by using formulae or available regression equations
3	Relief	Runoff and sedimentation (rate and volume), treatment details surface storage, operational convenience	(a) Mean elevation (b) Average slope (c) Geomorphic units (d) Total relief (e) Relief ratio	Topographic maps, aerial photos, satellite images and block diagrams and using respective formulae
4	Drainage	Runoff and sedimentation channel treatment, surface storage, operational convenience	(a) Drainage pattern (b) Stream order (c) Drainage density (d) Mainstream length	Topo maps and aerial photos, satellite images and using respective formulae
5	Geology	Sedimentation and runoff, groundwater, construction material, structure foundation	(a) Type of rocks (b) Stratagraphy	Geological maps, reports, satellite image interpretation combined with field surveys
6	Soils	Runoff and sedimentation treatment details, production potential, proper land use, operational convenience	(a) Soil phase (b) Morphological, physical and chemical properties (c) Hydrologic soil groups (d) Soil moisture regions	Soil survey reports and maps, satellite image interpretation combined with field surveys
7	Climate	Runoff and sedimentation treatment details, proper land use, production potential operational convenience	(a) Precipitation (b) Temperature (c) Humidity (d) Wind Velocity (e) Sunshine hours	Meteorological records, reports and other publications
8	Surface condition and land use	Runoff and sedimentation groundwater soil moisture treatment details, operational convenience	(a) Present land use condition (b) Natural vegetation (c) Canopy percent (d) Hydrologic cover condition (e) Existing tanks (f) Communications	Revenue records, forest working plans and reports, toposheets, serial photos, satellite images and ground survey
9	Ground water	Runoff production potential, operational convenience, treatment details	(a) Water table contours or depth (b) Quality of groundwater	Groundwater survey reports, existing wells
10	Social and legal status	Treatment details, operational conveniences watershed sufficiency/ deficiency in food, fodder and fuel, animal and manpower, acceptance, follow-up and maintenance of programmes runoff and sedimentation	(a) Human and animal population (b) Land holdings and tenure laws (c) Existing management level (d) Land and water development legislation	Census reports revenue records, district gazetteers, legislations

community and the larger watershed area The plan should emphasise action on local problems, both community-based and individual farm-based An emphasis on change of land use should be laid. Afforestation of privately held woodlands, agro-forestry, dryland horticulture, silvipasture on private plots, control of grazing and fire in private or village forests, agronomic practices and land management, gully stabilisation and other types of erosion control, improvement of vegetative cover on pasture, etc., should be included.

(c) *Farm plan.* On privately held arable lands, and to some extent on grazing and forested lands, the basic element in the structure of planning for watershed improvement is the farm plan. Every land user has some sort of plan, which usually has hap-hazard pattern of decision-making. It is essential that WDP should include individual farm plans These farm changes must be planned against the changing watershed conditions and against the background of the economic and social objectives of the farmers Such plan should be 'whole farm' plan. They must be related to land use and also to many other aspects of the operations of farms and the lives of farm families.

(d) *Problem spot plan.* They relate to the more critical areas in a watershed from the point of view of runoff and erosion and for the most part they cover the actions to be taken by the public agency concerned with watershed improvement For example, land slides, severe gully and ravine erosion spots, depleted CPRs, excessive water-mining areas, etc , need concentrated efforts. The remedial work on such areas is always expensive and great care must be taken to minimise the cost of the work Great care must be taken to not 'overinvest' in the improvement of these critical spots.

In short, WDP for a micro-watershed, which should be submitted by PIA to DRDA for sanction, should have following aspects

(1) Introduction (including past history)
(2) Physiographic features (topography, hydrology, edaphic conditions, land use, land capability/suitability classification, slopes, soils, distribution of PPRs and CPRs etc).
(3) Socio-economic features (social set-up, customs, traditions, occupations, agricultural practices, marketing, economic status, prevailing wages, supply/demand of fodder, fuelwood, literacy, population growth, migration, education and health facilities, credit facilities, sanitation, etc)
(4) Land literacy maps (showing ownership rights)
(5) Objectives and goals
(6) Entry point activities
(7) Proposed capacity-building, motivational and technical training programmes for project staff and watershed community (Plate 22 a, b)
(8) Treatment plan (for agricultural lands, CPRs, problem spots etc)
(9) Treatment plan (location of structures on village maps and plots numbers)
(10) Treatment plan (designs of various structures)
(11) Treatment plan (cost estimates)
(12) Integration of various welfare and development schemes
(13) Organisational set up/institutional building
(14) Managerial systems (for PPRs and CPRs)
(15) Monitoring and evaluation methods and strategies

Plate 22 (a, b) *Capacity-building, motivational and technical training programmes should be conducted for PIA members at regular intervals Similarly, exposure visits could inculcate motivation and direction in them*

9

Use of Remote Sensing Thematic Maps

Remote sensing is defined as the collection of information about an object without being in physical contact with it. This information can be in analogue or digital form In conventional aerial remote sensing (aerial photograph), this information is recorded in the form of photographic images, where different lensfilm/filter combinations perform as sensors In satellite remote sensing, the information is recorded through a more sophisticated system of various types of scanners/detectors/electronic recorder combinations and the data is stored on computer compatible tapes (CCT) either in analogue or digital form for its use later. Before information could be extracted from such raw data, it is corrected for geometric and radiometric errors. It is, therefore, inevitable that such voluminous data is processed and analysed through computers

Several advanced countries have their own remote sensing satellite regularly acquiring data that form the basis for resource studies Important remote sensing satellites in operation include the Landsat, SPOT, IRS, NOAA, MOS, ERS, Radarsat, etc (Figure 9.1).

The main areas of application of satellite remote sensing are as follows:

(a) *Geological applications* Regional geology and lineament studies, lithological mapping, alteration mapping and geomorphological studies

(b) *Agriculture and vegetation.* Forest mapping and inventory, vegetation/biomass productivity studies, crop yield estimation, vegetation stress/damage detection and habitat analysis

(c) *Soil and water resources·* Soil mapping, wasteland mapping, soil-vegetation association, surface and groundwater studies, reservoir studies, flood mapping catchment and command area surveys.

(d) *Environmental and natural hazard studies* Detection of soil films, landslides, erosion, deforestation and forest fires

(e) *Land use and land cover analysis.* Land use mapping, settlements, integrated land resource surveys

A detailed database on natural resources, terrain conditions, socio-economic status and demography is a prerequisite to prepare action plan keeping in view the underlying concept

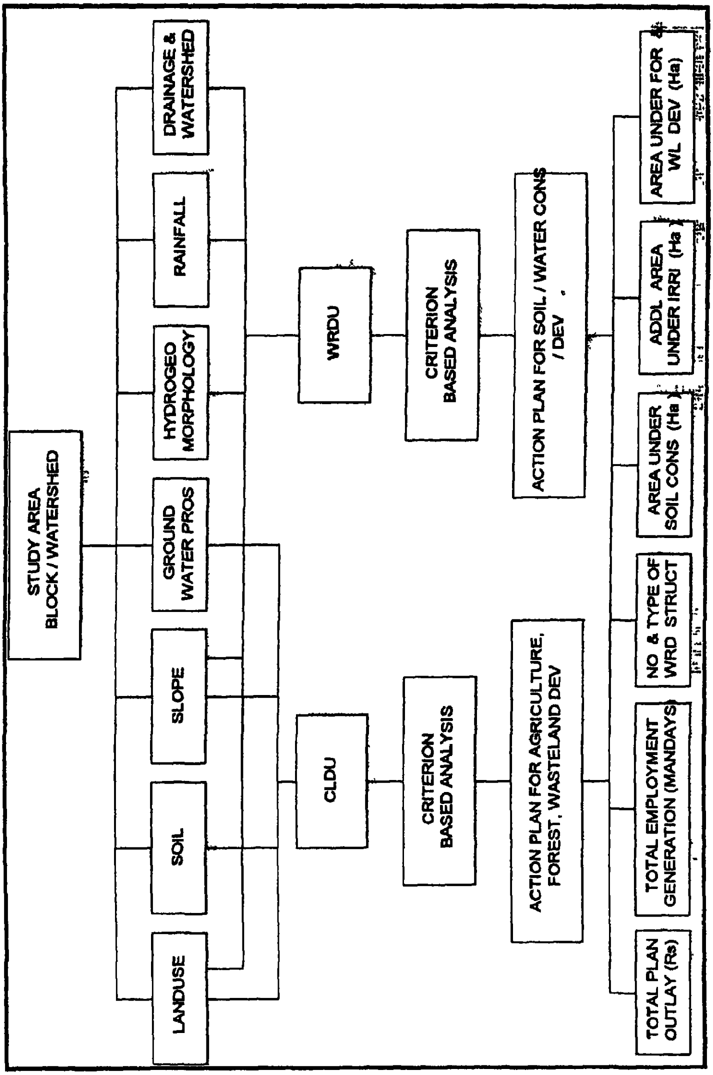


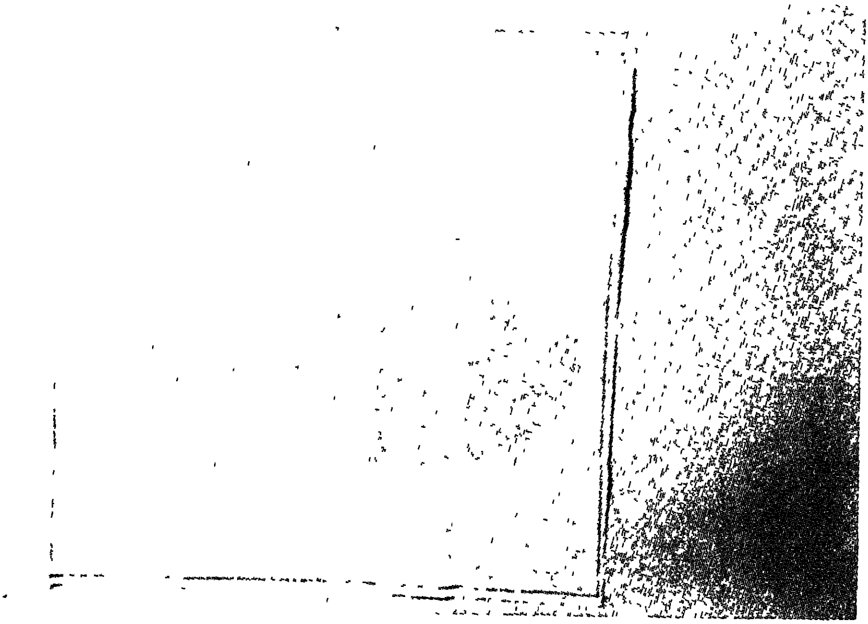
Figure 9.1 *Natural resources data analysis*

of sustainability. Considering the geographical extent of watershed area, the level of planning, time-frame for the project, spatial resolution of operationally available satellite data for using the same as input for achieving speed and efficiency in mapping should be chosen It has been the practice to generate thematic maps on 1· 50,000 scale. Accordingly, the Survey of India topographical map details for various themes are superimposed Adequate ground features as available on the topo-maps should be shown on the base map for facilitating quick ground referencing The overall size (dimension) of the map should be limited to a standard topo-map on 1 50,000 scale in general However, efforts should be made to accommodate a small area falling in the adjacent toposheet keeping in view that the shape of the area and dimension of the map is limited to 80 cm width.

Commonly used thematic maps

Various thematic maps are commonly used in preparation of action plan of watershed areas (see Appendix 1 to 8, also see Plate 23)

Plate 23 *Remote sensing thematic maps provide valuable technical inputs for micro-planning*



Soil thematic maps

Following different kinds of surveys are available

	Descriptive term	*Scale range*
1	Intensive	1.10,000 to 1 50,000 or more
2	Detailed	1 10,000 to 1 25,000
3	Semi-detailed	1 25,000 to 1 50,000
4	Reconnaissance	1 1,00,000 to 1 5,00,000

However, for the present, the common practice is to use detailed, semi-detailed and reconnaissance surveys.

Satisfactory delineation of soil boundaries can be done in reconnaissance and semi-detailed surveys using satellite data (IRS) and aerial photographs of medium and small scale (1:25,000 to 1:15,000 and 1·50,000 to 1:100,000) with varying quantum of field work Reconnaissance level of mapping is mostly used by the planners and requires limited field checks. Imagery of 1:50,000 scale is the best tool for planning purpose mapping. Priority areas, thus delineated with imagery interpretation, can be taken up for semi-detailed surveys.

Maps result from surveying of soils, i.e., studying and describing soils in the field; identifying soil taxonomic units and naming them, classifying kinds of soils into units, locating and plotting soil boundaries on base maps; studying the behaviour of soil when used for crop production, forestry, grazing and a variety of other purposes, and synthesising the interpretation of the survey that predict the behaviour of different kinds of soils used in different ways

(i) The map scale should be such that it fits the need of the user. Larger scale maps are time-consuming, expensive and too large for the requirement.

(ii) Criteria should be listed for resource evaluation.

In the interpretation of image the problem resides in differentiation between features that are relevant for the given purpose and those that are not Based on the properties of image it is possible to classify the terrain phenomena into two main groups.

(i) Features that are directly visible in the image (e.g., land use and relief)

(ii) Features not visible in the image, but about which information can be deduced from related phenomenon that are directly visible (e g , soil conditions)

This means that information about soil conditions is only available on remotely sensed data, when the soil is directly visible (no vegetation cover) or when soil properties can be deduced from visible phenomenon such as relief, land use and natural vegetation The interpretation of the image for deducible feature is based upon the knowledge of the spatial correlation association between the different landscape features, such as topography and soil condition Soil associations occur in repetitive pattern, the delineation in general can be observed to see if a change in land use, slope, drainage pattern, hydrology or other feature has occurred Appearance of black and light coloured soils and sediments is unique on IRS bands It also gives implied information about topography which is an important factor for soil variation

Satellite imagery is a useful tool for preparation of soil association maps One image covers so large an area that regional relationship becomes apparent, this aids in assessing the effect of soil forming factors as well as providing a means of checking the pattern of soil association over most or all their areas of extent. Once the soil composition of each land unit is established, the interpretation of the imagery can be done for entire area by extrapolation Thus, a physiographic soil map is prepared, though it cannot directly depict soil depth

Digital analysis helps in delineating the boundaries of the various physiographic units more accurately Image processing and enhancement techniques are applied In most of the cases, holistic approach is useful Soil map is indirectly used to infer the infiltration characteristics of various soils, and in turn the runoff potential in the watershed

Land use/land cover thematic maps

Information on existing land use/land cover and pattern of their spatial distribution forms the basis for any developmental planning. The current land use has to be assessed for its suitability in the light of land potential before suggesting alternate land use practices The current land use/land cover maps can easily be prepared. Any category of land use/land cover in a study area, which is not covered under the purview of the following classification system, can be put under the category 'Others'. The forests are to be classified with respect to their type (i e., evergreen/semi-evergreen or deciduous) and crown density (i e, dense-40% crown density; and open/degraded-10 to 40% crown density; forest with upto 10% crown density should be classified as scrub forest). The system of classification for notified and non-notified (revenue and other) forests should be the same. However, the area estimates for the non-notified forests are to be shown separately in the report Also, the forest encroachments for agricultural or other purposes should be shown as per the actual land use and area under such categories should be recorded under area statistics for notified forest land.

The forest boundaries have to be taken from Survey of India maps of the same scale and incorporated in the base maps. Forest department is to be consulted for latest information on forest boundaries. Similarly, in respect of agricultural land, boundaries of the command areas as obtained from respective Command Area Development Authority are to be depicted in the map indicating the geographical extent of the command area. IRS geocoded on 1.50,000 scale pertaining to two periods, i.e, *kharif* and *rabi* seasons (preferably of the same agricultural year) are to be used for this purpose. However, digital data can be used if digital classification is employed Besides other collateral data as available in the form of maps, charts, census records, reports and especially topographical maps on 1·50,000 scale should be used The imagery has to be interpreted and ground checked for corrections.

This is essential to maintain high standards of map accuracy The quality assurance checks should be carried out twice, i e., (i) at field interpretation stage, and (ii) at field verification before finalising the map The field verification should be undertaken in all categories of mapping units occurring in the map sheet The final output would be the land use/land cover map on 1:50,000 scale These maps are very useful in the assessment of the runoff and soil erosion potential of the watershed

Hydro-geomorphological thematic maps

Information on landforms is an important input for land management, soil mapping and identification of potential zones of groundwater occurrence The aspects of morphography, morphogenesis, morphochronology and morphometry are vital inputs in preparation of geomorphological maps Apart from the landform characteristics, the geological information like lithology/rock types and structures also play an important role in identifying the groundwater potential zones Hydro-geomorphological map should contain the above mentioned aspects.

The hydro-geomorphological map is to be prepared by demarcating the geomorphic units and forms All available geomorphic units and forms are to be listed after interpreting the study area All the listed geomorphic units and landform details have to be grouped/classified as per the origin like fluvial, aeolian, structural, etc The geological details like lighology/rock types and structural details are also to be delineated using available geological/geomorphological maps of the area. Then, such geological details are incorporated on geomorphological map, since this information is necessary in identifying the groundwater potential associated with each geomorphic unit. For instance, pediment/pediplain without fractures/joints and lineaments normally have moderate to poor groundwater prospect, whereas the same geomorphic unit with a network of fractures/joints indicates good groundwater prospects. Similarly, a pediplain area of crystalline/ metamorphic rock is generally marked by poor to moderate groundwater prospect wherein the same unit in sandstone or limestone/sedimentary rock can have good to moderate prospects. Hydro-geomorphological map should consist of geomorphic unit, forms, structure, lithology, description and the groundwater prospects.

Summer season satellite images and the Survey of India topomaps are the main input data for preparation of hydro-geomorphological map. The geomorphic units are to be delineated based on the image characteristics like tone, texture, shape, colour, associations, background, etc. In addition, *rabi* season image has to be referred to for more details and correlation. During the interpretation of the thematic maps whenever some doubtful units are encountered, the same should be noted for ground checks. All the details like geomorphic unit, structure, lithology and prospect of groundwater should be checked.

The ground truth is to be undertaken based on a pre-determined traverse plan and the doubtful units encountered during pre-field interpretation should be verified and correctly incorporated on the map. Efforts should be made to check all the geomorphic units and geological features during the ground truth in order to enhance the accuracy. Apart from the above, quantitative parameters with respect to groundwater potential against each geomorphic unit should be indicated wherever possible The data available from central and state departments can be referred to for this purpose. Required changes should be incorporated carefully on the map based on the ground observation

Besides slope maps, drainage maps are also commonly used The thematic maps provide detailed information regarding major characteristics of watershed

Integration of information in thematic maps and generation of action plan

Action plan for the area should be optimally suitable to the terrain and to the productive potential of the local resources, so that the level of production is sustained without decline over time. The recommended activities of the action plan should take into consideration the contemporary technology and the resources, climatic and terrain parameters.

The integration of the aforesaid aspects, though very complex, can be achieved systematically through the following steps

Step-1: Study of individual theme maps

The individual theme maps are to be studied by multidisciplinary team in order to make a spatial assessment of the relative variations of resource potential and range of terrain conditions In order to facilitate this analysis, the range of parameters (resource units) in respect of each theme can be listed for the study area. This analysis helps in understanding the peculiar nature of the area and its related problems which need special attention. For example, problems unique to a particular area like drought, flood, wasteland and land degradation, overexploitation of groundwater and forest, hilly terrain, tribal areas, coastal zone areas can be inferred from this quick analysis. For a study area of one standard toposheet on 1·50,000 scale, this step should not take more than one day for a multidisciplinary team

Step-2: Study of theme maps in combination

This step is an extension of the preceding step wherein the natural and logical association of parameters of one theme *vis-a-vis* those of the other themes are studied For example, if two resource themes are to be studied and each resource theme in turn has five parameters, then theoretically there are 25 ways in which parameters can be associated However in nature, all such combinations may not and most often do not exist. With logical explanations, some workable combinations can be arrived at and odd combinations can be ruled out This association analysis helps in better understanding of the cause and effect in respect of not only problems/limitations but also about the potential that exists in the study area The spatial analysis of the theme maps rule out the possibility of missing any special aspect. At times it also throws light on any special aspect which otherwise is not very evident on the face of any resource theme. For a multidisciplinary team, this association analysis for one standard toposheet should not take more than two days.

Step-3: Development of decision rules for action plan

(i) *Land resources development and management* During this step, a multidisciplinary team undertakes an extensive and quick visit to the study area A number of spot observations are made by the team covering almost all types of landform, soil, slope, groundwater potential and quality, rainfall and climate zones, present land use, etc. Each spot is to be marked on the topographic sheet on 1.50,000 scale with special annotation for cross reference purposes. At each spot, the land characteristics (parameters) as mapped in the respective theme maps are recorded along with the present land use A few pertinent site conditions with respect to soil moisture, native natural vegetation and any other aspect, which are not reflected in the thematic maps are also recorded The existing cropping pattern and irrigation practices are also noted Upon noting these details, a short deliberation is made on the optimality of the present land use especially keeping in view the sustainable production and quality of ecosystem. If the present land use is considered sub-optimal, then a few possible options for such a site are discussed with an aim to achieve optimality within the overall framework of sustainability of production Unless and otherwise the present land use is beyond the threshold limit of some land parameters, a drastically different option is not recommended, since such a change will not meet with high level of acceptability. For example, a land unit which is ideally suitable for horticulture or fodder and fuelwood plantation, if is presently under agricultural practice, then a modest change such as agro-horticulture or agro-forestry is recommended However, for a similar site, if the slope is very steep. then it becomes the limiting factor Hence, agricultural practice is ruled out and an altogether new land use practice like silvipasture or fodder and fuelwood plantation is recommended The threshold limit of a particular parameter *vis-a-vis* its consideration for a particular recommended land use practice varies from area to area

Further, while making alternate recommendations for land use practice, futuristic considerations such as exploitation of groundwater, if presently not exploited, and possibility of adopting a more efficient system of irrigation and water management and other site improvements through soil and water conservation are also kept in view

Availability of improved varieties of crops, trees, shrubs and grasses and advantages of interdependency of agriculture, livestock and other practices, as in case of integrated farming system that have been made available through contemporary research, are also taken into consideration

Thus, with these considerations, finally an alternate land use practice is recommended for the site suitable for its recorded parameters In similar manner, more such observations are made.

Spot observations should be made with high level of intensity though the intensity will vary depending on the variability existing in the study area All these observations are to be compiled as per the recommended land use options/practices Accordingly, for a particular recommendation or combinations of recommended land use practices, various types of combinations of land parameters are developed which serve as the decision rules for integration of thematic maps and preparation of action plan. A decision rule has to be area specific and therefore has to be developed for each study area On preparation of the decision rules, the same may be discussed with experts/specialists in land management and farming systems research. Views of the selected farmers and local line departmental officials of the study area should be dovetailed to the decision rules

(ii) *Water resource development and management* The water resource development and management influence the land resource management to a great deal Therefore, it is necessary to develop, conserve and efficiently utilise the available water in soil profile and groundwater

Step-4: Preparation of draft action plan

The action plan can be prepared using the decision rules in two ways

— Overlaying of thematic maps through GIS/computer

— Manual overlaying of thematic maps using light table

(i) *Thematic integration through GIS* In order to use GIS and computer, the thematic maps need to be digitized, coded and stored using GIS software packages Intersection of various theme maps can be done by overlaying one theme over the other progressively and by applying suitable decision criteria as suited to the terrain under study The final composite units will enumerate various types of homogeneous units/polygons These would fit into one or the other combinations of the decision rules and can be assigned to the corresponding recommendation Accordingly, all such homogeneous polygons can be assigned to other recommendations as per the decision rules Wherever GIS and computer facilities exist, efforts are to be made to integrate the theme maps using the same keeping the overall time frame of the project in mind

(ii) *Thematic integration through manual method* Almost in a similar manner, the manual overlaying of theme maps is carried out However, in manual overlaying, the intersection of thematic mapping and generalisation are done simultaneously Any theme map can be used as a base to start with However, a theme map with maximum number of polygons can be used as base advantageously Accordingly, land use/land cover map can be used at the base Then, other theme maps, namely, slope, landform (from hydro-geo-morphological map) are super-imposed and the composite characteristics with the decision rules are analysed for assigning the recommended practice. For working convenience and simplicity only one type of land use/land cover unit is taken at a time for integration with other themes and for assigning a recommended practice. Subsequently, other land use/land cover units are taken for integration progressively in a similar manner.

The action plan thus generated should be considered as draft action plan

Step-5: Finalisation of action plan

The draft action plan is to be discussed with line department officials, district administration, local research centres, NGOs working in the area and farmers for their feedback. On suitable incorporation, the draft action plan has to be validated on the ground for improving the accuracy. The action plan is then finalised by incorporating the field observations. The final action plan maps should also have the village boundaries and watershed boundaries on them. The area statistics for various action plan items should be computed for each village and micro-watershed and are to be compiled for the entire milli-watershed.

Role of remote sensing in monitoring the impact of action plan

It is necessary that the means of monitoring should be very objective and unbiased Remote sensing techniques and GIS have been employed to assess the resource status for the purpose of generating the action plans. Therefore, it is appropriate that same means should be used, to the extent possible, for the purpose of monitoring. The feedback which would be obtained through the monitoring process will serve two vital purposes. At the first instance, it will provide the details and estimates of benefits accrued from the investment made in implementing the action plan and secondly such details will serve as vital inputs for making necessary modifications in the methodology adopted for study in future. Keeping the above in view, the following parameters for monitoring have been identified:

(a) *Land use/land cover parameters*: Important parameters under this category are
   - Surface water body-changes in number and areal spread.
   - Forest and other plantation-changes in area
   - Wastelands-changes in area in each type
   - Cropped area-changes in areal extent and cropping intensity (*kharif, rabi* and double cropped).

   The above mentioned details are obtainable directly from the land use/land cover map The land use/land cover map used for preparation of action plan can serve as a baseline data in this respect. Subsequent mapping should be undertaken at appropriate intervals, depending on the reported progress of implementation. Satellite data should be used for this purpose

(b) *Extent of irrigated area*: Changes in the extent of irrigated area, source-wise, can serve as an important indicator for knowing the effective utilisation of surface and groundwater. Apart from crop cover (especially during *rabi* season) as an indicator which can be seen from the satellite data, additional ground information regarding source of irrigation (tube-wells, dug-wells and small farm ponds) should be collected through groundchecks

(c) *Vegetation index* Normalised difference vegetation index (NDVI) is another parameter indicating status of biomass in the area. A fixed period in the year, appropriate to the study area, can be determined in advance for vegetation change study The relative error due to influence of rain preceding the period of study or any other influencing factor should be collected separately.

(d) *Fluctuation of depth of groundwater table, well density and yield*: Details on these parameters should be collected from the observation wells and satellite images. Standard method in vogue should be used for recording such data. Observation wells should be identified following the standard procedures.

(e) *Cropping pattern and crop yield (cropwise)*: Changes in these indicators with time partially indicate the impact due to recommended practices

(f) *Occurrence of hazards*· A systematic record of occurrence of hazards as reported in the area may indicate the impact of recommended practices and hazard alleviating measures.

(g) *Socio-economic indicators*· Some of the socio-economic aspects are influenced by the recommended activities/practices of the action plan. For example, many of the action items on implementation will generate more employment for agricultural labourers and often during off-season also. The same should reflect in reducing the migration of agricultural labourers from the area. Use of agricultural inputs could register an increase. Establishment of agro-industries in processing sector might take place in the area. Accordingly, following parameters have been identified for monitoring purposes. These are

- — Migration of labour and cattle
- — Use of agricultural inputs
- — Land value
- — Agro-based and allied industries
- — Duration of agricultural labour employment

Thematic maps vis-a-vis PRA excercises

Thematic maps and PRA excercises deduce numerous information regarding watershed characteristics which may be used in preparation of action plan. The Guidelines for Watershed Development, 1994, issued by Ministry of Rural Development, emphasise the strategy to be bottom-up Section (69) clearly highlights the specialist agencies like groundwater department, NRSA and other technical departments or institutions to conduct these surveys, which can be funded out of the 5% of works component released to the PIA for project formulation activities and revolving fund for SHGs. Section (66) highlights and emphasises three-day participatory rural excercises in each of the watershed villages The PRA excercises yield data regarding soil types, erosion, slope classification, fertility, rainfall, groundwater levels, surface runoffs, drainage lines, vegetative resources, forest species, grazing grounds, agriculture-allied activities, and socio-economic realities such as demographic details, social and wealth ranking, literacy, village crafts and skills, employment and labour opportunities, etc Both the methods have certain drawbacks, which create problems in preparation of action plan (see Chart 9 1)

It is a practical solution to use an intermix of the two methods. PRA excercises and land literacy (including house-to-house survey and field-to-field survey) should be taken up initially for community mobilisation, participation and organisation along with collec-

Chart 9.1 *Drawbacks of remote sensing*

(1) It is a costly excercise

(2) It consumes lot of time Very easily, six months may fly away before thematic maps finally reach the PIA. A long gestation period may cause over-expenditure in administrative head due to idle sitting staff and acts as hindrance in timely initiation of watershed treatment.

(3) MDT/PIA heavily depends upon an outside expert agency PIAs need a lot of logistic support to coordinate with NRSA/ expert team PIA may have to contact expert team, send them cadastral/boundary maps, toposheets, etc , collect thematic maps, help and assist them in groundchecks, retrieve the final products, etc. Even after that, house-to-house survey, field-to-field survey and other PRA excercises may have to be undertaken before finalising action plan.

(4) It is not a substitute for groundwork Duplication of work becomes necessary Without supplementation by ground check findings and PRA excercises, they may turn out to be disastrous

(5) Thematic maps on 1 50,000 have inbuilt limitations 1 cm on thematic map represents 0 5 km in the field Thus, a micro-watershed of 500 ha is represented by 4x5 cm in the thematic map Thus, finer details are lost

(6) There are lot of ambiguities in findings of thematic maps and field realities A particular location in the map may be untraceable Even a very predominant land form may never find a place on thematic map Field staff may feel frustrated by not being able to trace the map on the field

(7) It is alien to the PIA Remote sensing thematic maps are not very familiar, so field staff may get confused Technology aversion, when existing in MDT, may create difficulties in implementation of the action plan

(8) A team of experts may provide detailed thematic maps of 8-10 micro-watersheds in the district But what happens when the district (say like Jhabua) has undertaken 218 micro-watersheds? Restricted supplies of thematic maps may act as a bottleneck in implementation of the programme in the district

(9) Similarly, monitoring and evaluation of each and every micro-watershed with the assistance of satellite imagery may not be possible A community-based monitoring and evaluation system has to be evolved

(10) It cannot judge ownership rights on the fields It may create problems in planning For exmaple, a wasteland identified on the thematic map may be actually a privately owned agriculture plot

(11) The technique misses out on community mobilisation and participation PRA, besides gathering data and information, mobilises the community

(12) People's problems, perceptions and priorities may be completely missed out Hence, the action plan would not reflect the real ground situation It would not include the desired interventions at all

(13) Makes planning top-to-bottom

(14) Suggested and recommended interventions are often prescriptive in nature

Drawbacks of PRA excercises

(1) Personal and social biases often pollute the information

(2) If the excercise is not broad-based and community involvement has not been ensured, then the outcome may be faulty

(3) The method may totally fail amidst not-so-friendly and/or hostile community

(4) Hydrology, geomorphology, drainage characteristics of the watershed may be totally missed out Thereafter, integrated development of the watershed may not be possible

(5) The holistic view of the whole watershed area may not be perceptible Inter-relations between factors may also be not possible to establish

tion of data on diverse facets. Action plan should be based on these findings. The remote sensing thematic maps, when become available, should be used for supplementing the action plan. These maps should be used to provide general framework for the interventions and activities in the action plan. 1.12,500 thematic maps, if possible, should be used, as they ensure more detailed information. They may be effectively used in identification of location for cost-intensive and crucial structures like percolation tanks, sub-surface dykes, etc

10

Indigenous Soil and Water Conservation Practices and Agronomic Measures

Soil erosion is a problem affecting on-farm and off-farm lands. Soil erosion causes loss of valuable moisture and nutrients. The topsoil is washed away leading to decline in crop yields. Downstream rivers, lakes, tanks become silted. Soil particles transport pesticide residue poisoning downstream water. Soil erosion costs farmers and community a fortune. There have been instances of debates among the experts regarding the cost effectiveness of soil and water conservation structures. Information is scarce about both the actual costs of soil erosion and the implications for future welfare, if soil is allowed to degrade at a given rate (Seckler, 1987) The government is placing priority on measures to control soil erosion. Between 1969 and 1990, the budget of soil conservation was Rs. 16 billion.

Soil and water conservation in a watershed context is believed to increase agricultural productivity in dryland areas. But there seems to be an impression that farmers do not willingly adopt recommended SWC measures

Farmers in semi-arid tropical areas of India have developed effective, indigenous SWC practices. These indigenous technologies have evolved in response to agro-climatic, ecological and economic conditions. The indigenous SWC designs vary with site-specific agro-climatic factors. The relative availability and opportunity cost of different resources like materials, human labour, animal power, cost, etc , decide the designs of indigenous SWC structures. The indigenous designs have been developed within the constraints of small and fragmented farms. The preference has been individual or in cooperation with adjacent farmers rather than in large cooperative groups. These designs have been developed and maintained by certain forward-looking, advanced farmers of the community. Due to the costs involved, rarely one sees the whole community adopting such measures at their own costs. The opportunity costs and constraints for each price of land are different, so the same SWC measures can never be profitable to all farmers equally So, farmers choose among alternative investment possibilities, some of which may be more profitable than SWC measures Available alternative investment possibilities, tenural status, the number of owned plots and resources available decide the acceptance of SWC measures by farmers

Farmers may lack complete information regarding on-site cost of soil erosion. Alternatively, they may be reluctant to make investments with variable long-term returns. If the costs of erosion are downstream or off-site or if tenural rights do not exist, then the farmer is constrained to invest. Understanding locally prevalent SWC indigenous practices and their adoption patterns are important for planners and implementors of watershed development.

Reasons for rejection of recommended SWC practices

There have been differences in perceptions regarding problems and approaches to solve them among planners and farmers. Due to lack of coordination among various line departments even in watershed programme, the soil and water conservation is often taken in isolation (Vaidyanathan, 1991). On the other hand, farmers have multiple objectives of which SWC is only one. Contour bunds for a project implementing agency may only be important for SWC, but farm bunds demarcate property lines and protect against encroachment by a neighbour. They are often lined with thorny barriers to keep trespassers out. The bunds may be used by a farmer to produce valuable commodities like fuelwood, fodder or fruits. Farmers could only accept recommended SWC measures like contour bunds, only when they are constructed in straight lines. Only straight-lined bunds do not hinder tilling practices and facilitate partitioning land for inheritance. Indigenous technologies are boundary-based while recommended SWC structures are positioned on the contour Another difference is that indigenous SWC practices emphasise short-term productivity as well as conservation, while recommended SWC technologies are aimed at long term productivity benefits from maximum protection of the soil

SWC measures have been recommended in the form of continuous contour bunds which reduce runoff, increase infiltration and divert excess runoff to a central waterway. SWC engineers recommend that bunds be located on the contour, so that the pressure of runoff water is spread evenly. While indigenous SWC structures on small farms lie uniformly on field boundaries which rarely correspond exactly to contour Farmers use contour bunds on tank irrigated paddy land but use boundary-based erosion control measures on his rainfed land. Farmers recognise the efficiency of contour-based systems for SWC, but they feel that the benefits on rainfed land may be minimum or marginal. Indigenous structures are more diverse as they have evolved in multiple conditions. Boundary bunds are made either from earth or stone or a combination of both, depending on the relative abundance of these materials With the increase in slope, rainfall intensity and erodibility of soil, the bunds increase in height and width. Methods to dispose of excess runoff are also boundary-based In low rainfall red soil areas, farmers build small earthen bunds to keep all the moisture on the fields In medium rainfall black soil areas, farmers construct stone waste weirs(drains) to dispose of runoff into the fields below theirs, protecting the fields from waterlogging. In high rainfall zones, the waste weirs deposit water into boundary waterways, protecting the lower fields Sometimes, grass strips are planted on the lower end of the field to arrest soil, while allowing the water to drain In hilly terrains and tank-irrigated low land areas, contour farming is widely practised

Prevalent indigenous SWC practices

A detailed comparison of recommended and indigenous practices in different agro-climatic zones is shown in Table 10.1 Contour bunds will not gain widespread acceptance on small farms. Farmers will not accept contour bunds alongside boundary bunds because they occupy a chunk of space in a small farm Contour bunds without boundary bunds will also be not acceptable to them as the soil below the contour bunds will move downhill into other farmer's fields. Conventional and recommended SWC measures appear to be suitable only where landholdings are large Conservation methods are undertaken and adopted only if they are profitable. Soil conservation methods that produce rapid returns on investment are the most accepted Bunds with small investments, controlling moisture and also used for fuel and fodder production will be acceptable to the community. Farmers would only accept SWC measures which concentrate soil at appropriate locations, rather than merely conserving it (Kerr and Sanghi, 1991) There are examples, especially in hilly tracts, where some farmers induce erosion in the upper end of their holding in order to concentrate soil in the lower parts. Farmers in low lands control rills and small gullies in their fields with small stones or boulder checks across the flow. Silt fills behind the stones until the area is level. Similarly, to control gullies, farmers build loose boulder checks with vegetative barriers on the boundary lines to conserve the soil. Over the years, the height of these barriers is increased Field bunds may be lined with fodder grass or other useful plants, both to strengthen them and provide additional income.

Table 10.1 *Recommended vis-a-vis indigenous SWC practices for different agro-climatic areas*

	Objective	*Recommended SWC practices*	*Indigenous SWC practices*
(a) *For low rainfall, black cotton soil areas*			
1	Gully control	Stone checks at regular intervals to stabilise gullies	Stone checks on boundary to harvest soil and reclaim gullies
2	Runoff disposal	Earthen hooks on contour bunds	Field to field through stone waste weirs
3	Water harvesting	Percolation tanks	Farm ponds, earthen embankment
4	Moisture conservation	Contour farming	Deep ploughing, land levelling Kharif fallowing 2-3 intercultures, soil mulching
5	Soil conservation	Continuous contour bunds	Field bunds with waste weirs
(b) *For low rainfall, hilly areas*			
1	Gully control	Stone checks to stabilise gullies	Stone checks on boundary to harvest soil
2	Runoff disposal	Earthen hooks on contour bunds	Field to field through stone bunds
3	Water harvesting	Farm ponds	—
4	Moisture conservation	Contour farming	Stone mulching, frequent shallow tillage, interculture
5	Soil conservation	Continuous contour bunds	Stone bunds on the boundary
(c) *For low to medium rainfall in red soil areas*			
1	Gully control	Stone checks to stabilise gullies	—
2	Runoff disposal	Field to field through earthern hooks	Field to field through stone waste weirs, boundary waterways
3	Water harvesting	Farm ponds	Percolation tanks, community tanks

Contd

Table 10.1 *Contd*

4	Moisture conservation	Contour farming	Short-term fallowing, fallowing at sowing, interculture, cross ploughing in standing crop
5	Soil conservation	Continuous contour bunds	Stone checks across hills, field bunds waste weirs, field drains waste weirs
(d) *For medium to high rainfall, red soil areas*			
1	Gully control	Stone checks to stabilise gullies	—
2	Runoff disposal	Central waterways	Boundary waterways, field to field through waste weirs
3	Water harvesting	Farm ponds	Divert runoff by gravity flows
4	Moisture conservation	Contour farming	Cris-cross ploughing, short-term fallowing, frequent interculture, tied ridging, seeding across major slopes
5	Soil conservation	Graded bunds	Field bunds with waste weirs, field drains with waste weirs, vetiver grass on field bunds
(e) *For high rainfall, black soil areas*			
1	Gully control	Stone checks to stabilise gullies	Stone checks on boundary to harvest soil and reclaim gullies
2	Runoff disposal	Central waterways, broad bed and furrows	Boundary waterways
3	Water harvesting	Farm ponds	Community tanks, post-rainy crops in tank bed
4	Moisture conservation	Contour farming	Interculture operations
5	Soil conservation	Continuous graded bunds, broad bed and furrow	Field bunds with conservation drains, field drains with waste weirs, grass strips on boundaries
(f) *High rainfall, hilly areas*			
1	Gully control	Stone checks to stabilise gullies	Stone checks on boundary to harvest soil
2	Runoff disposal	Central waterways	Boundary waterways
3	Water harvesting	Farm ponds	—
4	Moisture conservation	Contour farming	Frequent shallow tillage and inter culture
5	Soil conservation	Continuous graded bunds	Stone bunds on the boundary (across the major slope)

The planners and project implementing agency should understand the prevailing and acceptable SWC measures in small farms SWC measures in Integrated Watershed Development Programmes should be based on existing indigenous and appropriate technology So, the methods described in this chapter should be based on the local field conditions To achieve maximum output and impact, watershed programme should be flexible to include indigenous and recommended scientific practices The National Guidelines on Watershed Development, in spirit, encourage such an approach

Observation regarding indigenous SWC practices

Farmers in the community are aware of the soil erosion and have developed effective measures to control it. But even then, most farmers do not undertake sufficient SWC measures.

Farmers understand the erosion threat to their land and its effect on production, the requisite measures for prevention and cost involved. Farmers accept the fact that erosion leads to loss of soil, loss of water and loss of nutrients from their fields. Where soil is shallow, losing large amounts of soil is acceptable to them, however when soil is deep and erosion is mild they are more concerned about losing nutrients. Gully erosion is seen as reversible. Sheet erosion is perceived to cause irreversible damage, especially where soil is shallow. Farmers with substantial off-farm employment and income tend to invest less in soil conservation than those without. It has also been observed that usually farmers do SWC works with the help of family labour. It is only when returns are higher than the wages and the farmers have paying capacity, that hired labour is engaged in SWC works The opportunity cost of time changes seasonally for farmers, so the SWC works under watershed programme should preferably operate in slack and lean seasons.

Farmers invest less in SWC due to resource crunch or other investment priorities. It suggests that flexible soft loan schemes with minimal subsidies would help the farmers to take up such activities It has been observed that farmers who cultivate their own land are much more likely to invest in SWC than those renting or sharecropping someone else's land. The basic reason is that short-term tenants do not invest in long-term productivity measures because they are not likely to reap the returns (Venkataramana and Johnson, 1988). So it is important to adopt SWC measures in watershed programmes which have short-term returns as well. Modifications in tenural rights and absentee landlordship should be undertaken.

SWC measures are least expensive on land that has abundance of resources. SWC measures should take advantage of local materials in treatment. It has been observed that SWC investment is higher on potentially productive land Farmers are more concerned about erosion on good land than on bad land. Irrigated land receives the most of SWC investment Farmers who operate both irrigated and unirrigated land appear to invest little in SWC on their unirrigated plots. It has also been observed that farmers build SWC structures in stages which postpone costs, and short term financial constraints are mitigated For example, farmers start with low and small boulder checks to control gully erosion and increase their size and height every year with increase of silt deposition.

It is also observed that there is much potential for cooperation by two or more adjacent farmers sharing a common boundary as long as the activity relates to that boundary Structures which are needed across farm boundaries, group action is difficult to initiate, since benefits and costs are distributed unevenly among the affected people.

Recommendations regarding indigenous SWC practices

1. Farmers' objectives and preferences regarding SWC measures should be clearly understood so that designed action plan is more appropriate and acceptable
2. SWC measures with maximum cost effectiveness should be adopted Heavy investments in private lands can never be propagated
3. Programmes should be planned and implemented in full participation with farmers in

order to identify, in advance, acceptable and unacceptable measures.

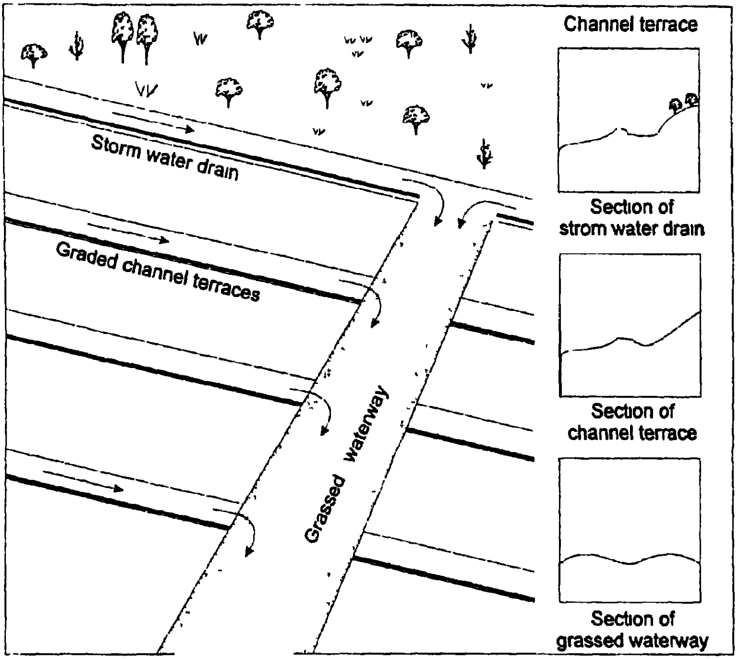
4. Education and training regarding usefulness and effectiveness of scientific measures should be taken up. But, incentives on rejection of indigenous practices and acceptance of scientific techniques should be avoided.
5. A comprehensive mix of indigenous and appropriate techniques should be worked out while finalising the action plan.
6. The current orientation towards measuring success by physical targets should be discouraged.

Certain major problems encountered in execution of SWC measures are shown in Chart 10 1. These field-related problems may also exist in other districts.

Agronomic measures for soil and water conservation

Soil and water conservation agronomy is as important as mechanical measures. Contour bunding or bench terracing are commonly adopted on agricultural lands for soil and water conservation. Generally speaking, soil conservation agronomic practices are second line of defence against soil erosion. Mechanical or engineering measures are first line of defence to arrest soil erosion (see Figure 10 1) Soil conservation agronomic practices have to be essentially considered in coordination with other measures.

Figure 10.1 *The basic components of mechanical protection*


Channel terrace
Storm water drain
Graded channel terraces
Grassed waterway
Section of strom water drain
Section of channel terrace
Section of grassed waterway

A) The stormwater drain which diverts storm runoff originating off the arable land
B) The graded channel terraces leading away the runoff from the arable land
C) The grassed waterway into which both stormwater drain and channel terrace discharge

Chart 10.1 *Major problems encountered in execution of SWC measures*

1 Imbalance in integrating technological inputs (like remote sensing thematic maps) and aspirations of the WA gathered from PRA/RRA, land literacy and house-to-house survey Either plans become too technocratic or become totally oblivious of any advanced technological input
2 Non-involvement and non-participation of SHGs and UGs in planning and execution of SWC measures
3 Faulty site selection for SWC measures
4 Time framework and space framework regarding SWC measures execution is ignored
5 Initiation of execution of some SWC treatment plan from lower ridges (especially from agriculture plotes) while it should have followed ridge-to-valley pattern
6 Faults in estimation of contour levels by using A-frame techniques by the community
7 Over-emphasis on contour trenches for controlling runoff and soil erosion on upper ridges
8 Undue importance given to continuous trenches Deviations in the contour levels may result in damages causing runoff and soil erosion
9 Either preponderance of temporary structures or preponderance of permanent structures depending on the whims and fancies of the PIAs
10 Ignoring integration of all relevant SWC strategies like agronomic and mechanical measures on agricultural and non-agricultural lands, water conservation and harvesting, groundwater management, conservation forestry techniques in right and holistic perspective Generally, undue emphasis is given on one aspect ignoring others
11 Overlooking groundwater artificial recharge and management
12 Difficulties and hurdles in execution of SWC structures in forest areas, reserved or protected, primarily due to stringent forest laws
13 More importance given to PPR development as compared to CPR development and management
14 Over-emphasis on field bundings, which are easily acceptable to the farmers and dominant sections of the community Boundary bunds are preferred compared to contour bunds The effectiveness and utility of such field bunds are doubtful.
15 Tendency to promote biomass ignoring biodiversity Selected and few species of fodder and plants are promoted
16 Cost-benefit analysis and social or technical evaluation systems are not inherently built-in
17 Stringent technical checks of SWC structures by PIA which hampers the progress and kills the local initiatives
18 Neglecting regular maintenance and repairs of SWC structures
19 Tendency to overdo SWC structure construction causing overcrowding of structures This may result in cost-escalation and decline in the effectiveness
20 Strategies to change land use (like agro-forestry, agro-horticulture, silvipasture development) are not duly emphasised
21 Neglecting equitable distribution and sustainability of SWC structures
22 Frequent diversions from SWC treatment plan included in the watershed action plan (WAP)

(These problems observed in certain micro-watersheds were reported by PIAs to DRDA)

Agronomic practices for soil and water conservation help to

(i) intercept rain drops and reduce the splash effect,
(ii) obtain a better intake of water rate by soil, by improving the content of the organic matter and soil structure,
(iii) retard and reduce the overload runoff, and
(iv) maintain *in situ* moisture.

The first step in water erosion is splash causing detachment of soil particles resulting from impact of rain drops followed by transportation through runoff water Soil conservation agronomic practices help in reducing the impact of raindrops through interception and thus reduce splash erosion. They also help in increasing infiltration rates and thereby reduce runoff and overload flow. Although, agronomic practices are considered as second line of defence in soil and water management programme, these are of immense importance Crop management practices are important means of soil and water conservation in agricultural lands The best crop management is the most intensive and productive use of the land without causing degradation Hudson (1957) suggests that crop management specifications for good erosion control are exactly the same as for maximum production and profit.

The effect of crop management factor 'C' can be visualised by the use of Universal Soil Loss Equation (USLE) for preventing soil loss

$A = RKLSCP$

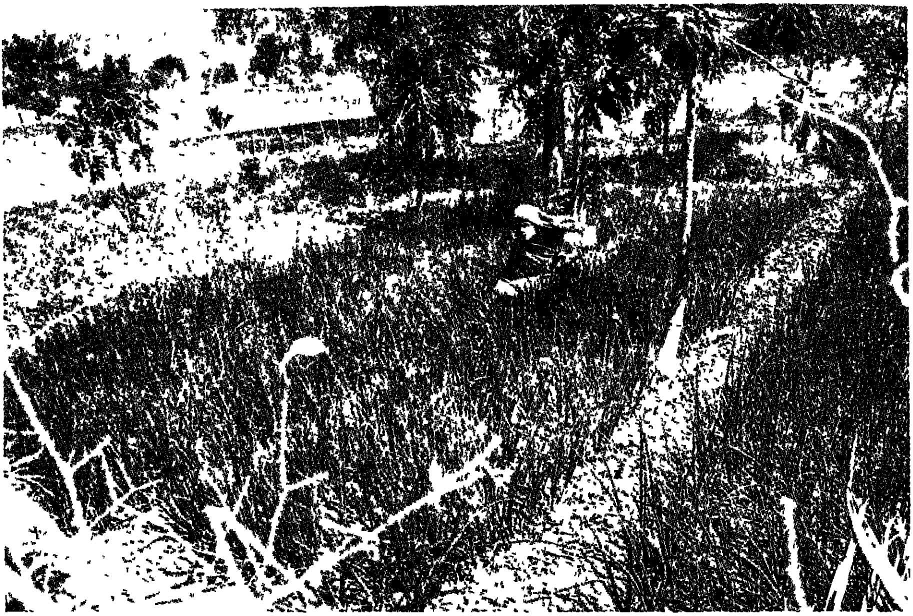
The factor of rainfall erosivity (R) and soil erodibility (K) are controlled only by nature The factors length (L), slope (S) and management (p) may have varied values of 1 under the worst conditions and at most be reduced to 0 50 through ideal soil and water conservation measures The effectiveness of crop management factor (C) is immensely important The worst practice may give a value of 1 00 for the C factor and ideal crop management can reduce it to as low a value as 0 05 or even 0 02 under a grass cover (Narain et al., 1982) Thus, by adoption of appropriate crop management, the soil loss from the problem area can be reduced to 1/50th of its pre-treatment value It can easily be stated that a conservation agronomic practice is 10 to 25 times more effective than other factors

Choice of crops

Earlier, crops were either called erosion-permitting crops or erosion-resistant crops Cereals were termed as *erosion-permitting crops* and legumes and grasses were considered as *erosion-resistant crops* Scientific research, over the years, has challenged the concept Fertility degradation is affected to a little extent by actual nutrient removal by the crops, but the crop management which allows more soil loss will degrade the soil irrespective of type of crop For example, an ill-managed crop produces 15 times more soil loss than a well-managed corn under identical conditions (Hudson, 1957) Even a well-managed corn produces less soil loss than an ill-managed pasture Thus, erosion depends not only on what crop is grown but on how it is grown Therefore, some crops are more prone to erosion due to the way they are grown Closely growing crops like grasses and good canopy-forming crops like legumes will cause less erosion (Plate 24 a, b)

In short, the division of crops into erosion-permitting and erosion-resistant is a myth. Numerous other factors affect the erodibility of soil, which should be taken into consideration for a comprehensive SWC agronomic plan

Plate 24 (a, b) *Cultivation provides not only nutrition and income but also assists in protection of soil form erosion*



Use of cover crop

Crop canopy, also called crop cover, is one of the important factors, which affects soil loss dramatically. Erosion from cultivated fields can be reduced if the land has sufficient crop canopy during the peak precipitation period. The soil loss is governed by the amount of exposed land surface Good crop cover or canopy gives a protective umbrella to the land. Studies have clearly shown that higher the canopy of the crop, the less will be the splash. Thus, with good ground cover, the splash effect of raindrops leading to soil erosion can be minimised

Studies at Dehradun, Vasad and Kota have revealed that cowpea provided an excellent cover to the ground which was followed by other legumes like velvet beans, sunnhemp, dhaincha, green gram, black gram and cowpea (Tejwani et al, 1975) Average results of four years (1961-62 to 1964-65) at Vasad have shown that good canopy reduced the splash. The decreasing order of splash was (also see Table 10 2)

cultivated fallow>cowpea>groundnut>green gram>sunnhemp

Table 10.2 *Canopy development and soil splash under different legumes at Vasad (average of four years)*

Treatment	*Average canopy (%)*	*Average splash (gm)*
Cultivated fallow	—	6 3
Cowpea	26 8	4 9
Groundnut	52 8	4 2
Mung (green gram)	37 4	3 9
Sunnhemp	42 3	3 3

It is important to understand that choice of crop should not only produce good canopy but also provide handsome economic returns to the farmers Pulse crops are generally suitable for such purposes.

Root factors

Plant roots are the best binding factors for soil Grasses have been found remarkable to control soil erosion and improve soil structure due to good canopy cover and good binding force shown by the grass roots Legume roots also help in improvement of soil structures, perhaps due to higher root mass and secretions, which help in binding of soil particles Very little to negligible soil, water and nutrient were lost from soil under grass cover, while bare fallow produced maximum soil loss (Gupta et al, 1963) (Tables 10 3 and 10 4)

Table 10.3 *Runoff and soil loss as influenced by grasses on 9% slope on silty clay-loam (average three years)*

Treatment	*Rainfall (mm)*	*Water losses (% of rainfall)*	*Soil loss (tons/ha)*
Cynodon dactylon	1250	27 1	2 10
Natural grass cover	1250	21 2	1 02
Bare fallow	1250	71 2	42 40
Bare fallow (ploughed)	1250	59 6	155 95

Table 10.4 *Soil and water loss at 1% slope, clay soil (average three years)*

Treatment	*Rainfall (mm)*	*Water loss (mm)*	*Soil loss (tons/ha)*
Dichanthium annulatum	701	20	0 06
Black gram	701	138	5 4
Soyabean	701	143	4 5
Cultivated fallow	701	175	8 9

Based on Narain et al, 1980

Land preparation

Land preparation (including post-harvest cultivation and preparatory tillage) influences intake rate of water, obstruction to surface flow and rate of soil erosion. Deep ploughing or chiselling of fields after crop harvest have been found to increase infiltration rate In drought-prone areas, emergency tillage operations are initiated on a large scale Maximum effect of land preparation on control of soil erosion is obtained in medium-textured soil (than sandy soil).

Minimum tillage is advantageous for SWC. In this process, the land surface is left least disturbed. The planting is done in one operation (plough-plant) or in two, i e , ploughing and planting If minimum cultivation is adopted in the cultivated fields, the soil structure is not destroyed and erosion is checked In minimum tillage plots on a silty clay soil at 12% slope runoff was greater than found in conventionally ploughed plots However, soil loss was reduced by 60% through minimum tillage (Chisel and Zauchi, 1980) (Table 10.5).

Table 10.5 *Runoff and soil losses (average of two replications) in relation to different tillage systems*

	Undrained		*Drained*	
	Runoff (mm)	*Soil loss (tons/ha)*	*Runoff (mm)*	*Soil loss (tons/ha)*
Conventional tillage	25 79	4 046	17 92	3 721
Minimum tillage	41 10	1 610	26 94	1 515
Pasture	21 11	0 184	15 85	0 150

Based on Khybri et al, 1980

Sowing time

Sowing date and correct seed rates are the backbone for a good stand and crop cover The sowing date should be so adjusted that at the time of peak precipitation periods, there is enough ground cover It is possible by advancing dates of sowing or even dry sowing in rainfed areas. Studies on maize (Prasad et al , 1980) have revealed that maize sown on 25 June gave higher canopy at peak rainy season and gave less splash as compared to crop sown on 1 July or 7 July The splash recorded with 25 June sowing was 25 9 gm as compared to 39.3 gm with last date of sowing Thus, a proper time selection for sowing is essential for higher production and protection.

Contour farming

During intense rain storms, the soil cannot absorb all the rain as it falls The access water flows down the slope due to gravitational force. If farming is done up and down the slope, the flow of water is accelerated, because each furrow serves as a rill The top fertile soil, along with plant nutrients and seeds, is washed off A simple practice of farming across the slope keeping the level same, as far as possible, has many beneficial effects In contour farming, the ridges and the rows of the plants placed across the slope form a continuous series of miniature barriers to the water moving over the soil surface. The barriers are so small individually, but as they are large in number, their cumulative and aggregate effect is great in reducing runoff, soil erosion and loss of plant nutrients. In regions of high rainfall, contour farming reduces soil loss, and in rainfed areas conserves moisture. The furrows between the ridges developed by contour tillage operations, catch and hold the water, helping in uniform distribution of moisture. Contour furrows, in pastures, help in better growth of grasses Since contour furrows store rain water at or near the point where it falls, this practice has a definitive value in controlling flash floods in small watersheds Apart from conserving the water and soil, contour farming conserves soil fertility and increases crop yields It has also been proved that much less power is exerted by men, animals and machines, if the cultivation is done on the contour instead of up and down the slope There is less wear and tear of the implements and the same job is done in less time when contour farming is practised

On long slopes, bunding is usually done to reduce the length of the slope These bunds will serve as a good guide for contour farming All operations have to be done parallel to these bunds On gentle slopes (between 0.5 to 2%) bunding may not be essential. Contour (the line passing through the points having the same level) lines can be marked with the help of hand level or A-frame On uniform slopes, these lines are to be marked about 50 m apart and farming is done parallel to these lines The slopes must be quite uniform, so that, a grade can be maintained in the crop rows, without the rows being too crooked and an excessive number of correction areas is not required to keep the grade within design limits (Table 10.6)

Table 10.6 *Effect of contour cultivation on runoff and soil loss on eroded alluvium soil at 2 2% slope*

Characteristic	*Along the slope*	*Contour cultivation*
Soil loss (tons/ha)	14 1	5 5
Runoff (mm)	348	249
Nitrogen (N, kg/ha) loss	20	9
Phosphorus (P2O5, kg/ha) loss	26	16
Potash (K_2O, kg/ha) loss	86	41
Humus (kg/ha) loss	140	60
Yield sorghum (kg/ha)	16	20

Adopted from Bhatia and Chowdhary, 1977

On steep slopes and under high rainfall conditions, contour farming alone can cause more harm than benefits There will be breakage of ridges and as the water flows downwards, cumulative flow increases. This may cause serious gully formations. Under such situations, the contour farming should be supplemented by other measures like terracing or bunding.

Strip cropping

Strip cropping consists of growing strips of various types of crops in the same field. In strip cropping, both close growing and row crops are grown in alternate strips in the same field. Broadly, strip cropping includes numerous agronomic practices that prevent erosion, build up soil fertility and improve the land capability. Such practices may include contour farming, proper crop rotation, cultivation of close growing and row crops, conservation tillage etc. (see Figures 10.2 and 10.3). Three types of strip cropping are in practice:

(a) *Contour strip cropping*: Tillage operations and planting of crops are practised along the contours. The width of the strips vary according to the horizontal spacing of the contour lines.

(b) *Field strip cropping*: When the land topography is very irregular and complex, the widths between two contour lines vary In such a situation, strips of almost uniform width across the general slope of the land are constructed. They do not follow any contour line.

(c) *Buffer strip cropping*: Buffer strip consists of planting of some grass or legume crops that completely cover the ground in between contour strips. Generally, they are used in regular rotation and are planted in the most critical areas. They provide better protection compared to other vegetation. Sometimes, the buffer strips are also used as 'correction/filler strips', when the widths of general strips vary too much, due to irregular topography.

Figure 10.2 *Crop rotation*

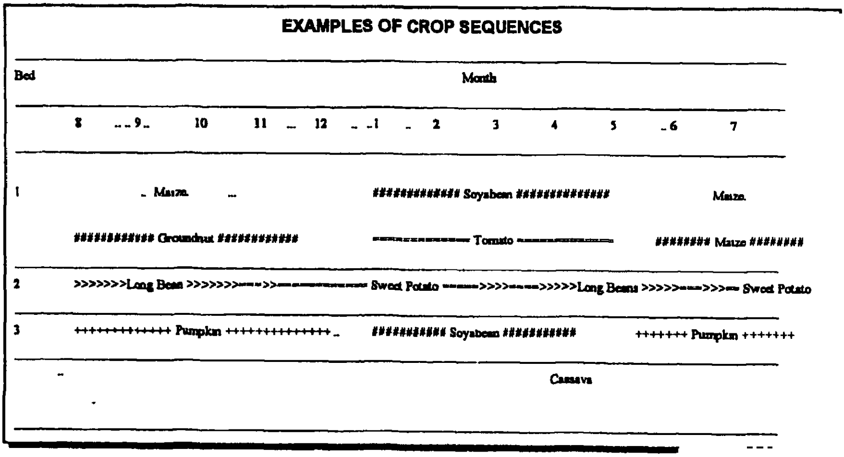
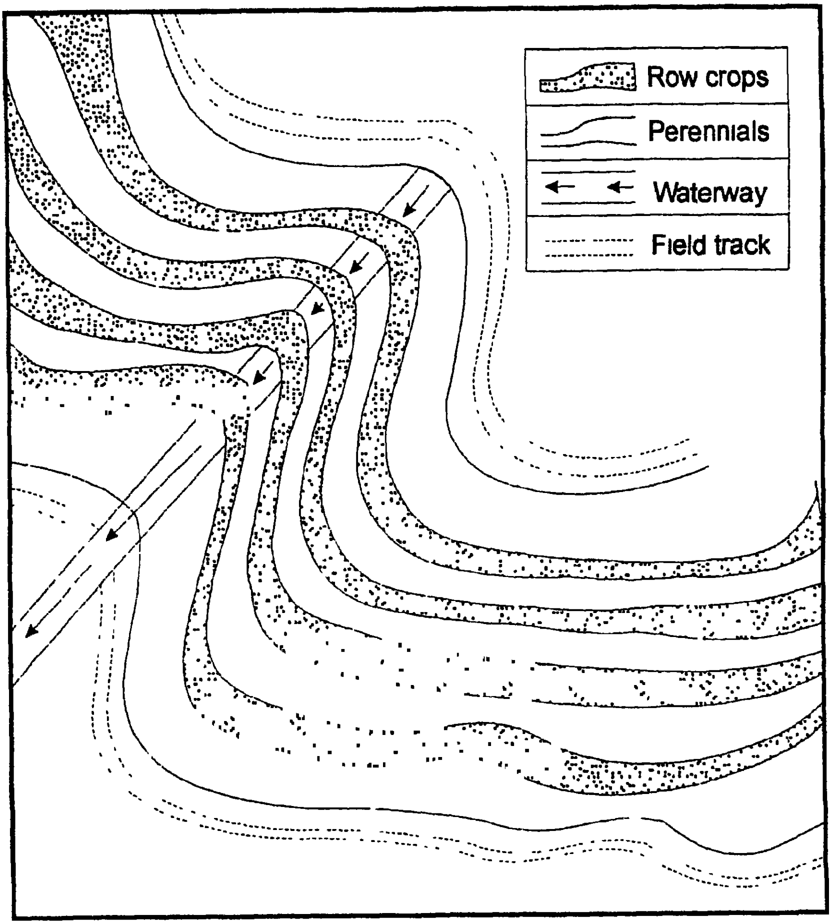


Figure 10.3 *Layout of strip cropping system*



For laying out a strip cropping system, following points should be taken into account:

(i) the width of the strip should be decided after taking into consideration soil, slope, rainfall and degree of erosion;

(ii) for maximum benefit, the strips should conform to the contours, as far as possible,

(iii) the strip cropping should fit into the existing and prevalent farming system,

(iv) regular rotation of the strips should be followed from year to year by shifting the erosion-resistant strips upwards, and

(v) the strips should be of sufficient width for economical farming

Generally, both edges of the strips are preferred on the contour A deviation of around 1% to 2% slope from the contour may be permitted (Table 10 7)

Table 10.7 *Runoff and soil loss as influenced by strip cropping on silty loamy soil at 8% slope (1978-80)*

Treatment	*Rainfall (mm)*	*Water loss (as % of rainfall)*	*Soil loss (tons/ha)*
Normal ploughing	1325.5	49.4	36.5
1/3 strip ploughing	1325.5	50.3	29.2
Normal ploughing+mulch @4 tons/ha	1325.5	22.3	6.2

Crop geometry

Optimum plant population and crop geometry are equally important to have an optimum crop cover. Denser plant population may be better from SWC point of view, but excess population may lead to severe moisture and nutrient stress on soil. This may consequently lead to crop failures under rainfed conditions. Besides the plant population, the geometry of the crop has great effect on soil and water losses (Table 10.8).

Table 10.8 *Runoff and soil loss at 4% slope on silty clay loam soil (average of three years)*

Treatment	*Rainfall(mm)*	*Runoff (% of rainfall)*	*Soil loss (tons/ha)*	*Grain yield (q/ha)*
45cm x 45cm	1282	47.8	22.6	15.47
60cm x 30cm	1282	39.7	20.6	15.38
75cm x 25cm	1282	33.9	18.5	15.77
90cm x 20cm	1282	33.0	13.9	14.46

Mulching

Mulching of open land surface is achieved by spreading stubble, trash or any other vegetation. The objectives of mulching are to:

(i) minimise splash influence of rain drops on base surface,
(ii) reduce evaporation,
(iii) increase absorption of the rainfall,
(iv) obstruct surface flow thereby retarding erosion,
(v) reduce excessive heating, and
(vi) allow microbiological changes to occur at optimum temperature.

Sometimes, spreading of organic residues, instead of mixing can help in reduction of soil and water loss to a considerable extent. Polyethylene mulches have also been utilised for water harvesting and control of seepage. Trash farming, in which crop remains are cut, chopped and partly mixed in ground and partly left on land surface is also a form of mulching. As most of the plant remains are used as cattle fodder, farmers may not adopt this practice under fodder scarcity conditions. Preparing a dust mulch on the open land surface may be helpful in conserving soil moisture.

Singh and Bhushan (1978) applied mulches immediately after the harvest of maize and recorded its effect on rainfed wheat. Mulching increased the yields of rainfed wheat significantly. Straw mulching before sowing was the best, giving 36% more yield than control. Dust mulch appears to be the most practical way of soil moisture conservation as it produced 22% more yield than control In semi-arid tracts, surface and vertical mulches significantly increased grain yield of sorghum (Ram Mohan Rao et al., 1983) Vertical mulch at 4 m spacing was found far more superior to 8 m spacing The yields nearer to mulch lines were higher than in middle of plot. The application of surface mulch was found to reduce temperature also (Table 10.9).

Table 10.9 *Runoff, soil loss and yield of maize under different treatments*

Treatment	*Runoff (% of rainfall)*	*Soil loss(tons/ha)*	*Yield (kg/ha)*
Mulching @ 2 tons/ha	17 9	7 3	2,317
Mulching @ 4 tons/ha	14 7	5 4	2,395

Mixed cropping

Mixed cropping is a practice of growing more than one mixed crop in the field simultaneously In mixed cropping, there is one main crop and one or two subsidiary crops Mixed cropping is very extensively adopted by Indian farmers It results into continuous and better cover of the land, good protection from the beating action of the rain, almost a complete protection against soil erosion and the assurance of one or more crops to the farmer (Plate 25) The roots of various species in a mixed crop feed at different depths in the soil

Plate 25 *Mixed cropping results in continuous and better cover of the land, good protection from the beating action of the rain, almost a complete protection against soil erosion and the assurance of one or more crops to the farmer*

Improvements in the practice of mixed cropping tend towards the rationalisation of the mixtures with respect to composition and content and towards better arrangements than from the usual medley of crops Mixed cropping is widely grown during the *kharif* season

Pulses and oilseeds are grown with maize, *jowar* and *bajra*. Low land rice is invariably grown unmixed, but in the case of upland rice, several mixtures prevail. During the *rabi* season, especially unirrigated areas of the north, wheat+barley and wheat+gram or wheat+barley+gram are the mixtures of grain crops. Brassica and safflower are grown mixed with gram or wheat. In mixed cropping, different crops can be more efficiently sown in alternate lines, instead of mixing the seeds, which is referred to as inter cropping (Table 10.10).

Table 10.10 *Effect of mixed cropping on yield of wheat and gram*

Treatment	*Yield of grain (kg/ha)*		
	1958-59	*1960-61*	*1962-63*
Wheat (pure crop)	370	458	176
Gram (pure crop)	573	499	—
Wheat+Gram (in all rows)	657	634	186

Adopted from Dhruva Narayana, 1981

Table 10.11 *Suggested crop sequential systems for different regions of India*

Region	*Crop sequence*	*Yield (q/ha)*	
		First crop	*Second crop*
Samba	Peralmillet-wheat	21.5	24.0
	Fallow-wheat	—	33.3
Dehradun	Maize-wheat	38.5	31.8
	Rice-wheat	43.1	29.9
	Fallow-wheat	—	16.2
	Maize-chickpea	30.3	25.4
Varanasi	Rice-chickpea	30.2	25.4
	Fallow-chickpea	—	35.7
Bhasiapur	Maize-wheat	27.3	27.2
	Fallow-wheat	—	23.2
	Maize-chickpea	27.3	15.3
	Fallow-chickpea	—	17.0
Bangalore	Cowpea-finger millet	8.6	27.5
		29.9	—
Akola	Sorghum-safflower	45.4	14.1
Anand	Cowpea-tobacco	8.2	9.7
Bijapur	Green gram-safflower	7.5	10.6
Indore	Maize-safflower	29.5	10.8
	Sorghum-chickpea	32.1	13.9
	Maize-chickpea	35.5	14.3

Weather aberration and crop sequencing

There may be delay in the rainfall, break in the monsoon, or withdrawal of rains before the normal time. The use of fertiliser along with efficient management could insulate dryland crops against moisture stress. Short periods of stress could easily be overcome by working the interrow soil with blade harrows for creating soil mulch (Table 10.11).

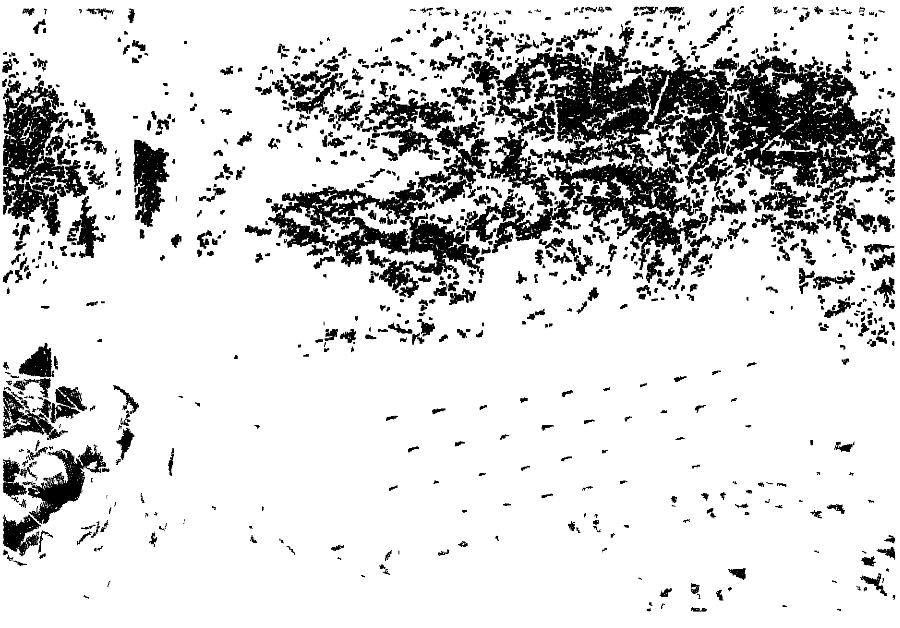
Land management

Land preparation, including post-harvest cultivation and preparatory tillage, influences intake rate of water, obstruction to surface and consequently the rate of soil erosion. Deep ploughing or chiselling of fields after crop harvest increases infiltration rate. Emergency tillage is done on a large scale in drought prone areas The *concept of minimum tillage* can be advantageously applied for soil and water conservation The planting is done in one operation or two, i e , ploughing and planting.

Adoption of organic measures and green manures

Organic manures and green manures not only supply plant food elements like fertilisers, but also help in improving soil's physical condition The fertilisers improve vegetative growth of crop/crop canopy and thereby reduce soil erosion Organic manures and green manures have slow nutrient effect and simultaneously improve rate of infiltration and soil structure, thereby slowing the process of soil erosion (Plate 26) Optimal use of FYM has positive effect on soil properties. Small doses of FYM may not influence soil properties appreciably, particularly in tropics, under rainfed conditions Under FYM, green manuring is more important in view of improvement in physical conditions and properties of soil as decomposition occurs *in situ* Green manuring is a common practice in irrigated or high

Plate 26 *Organic manure prepared in NADEP pits check soil erosion by improving infiltration of soil and soil structure*



rainfall tracts. In moderate or low rainfall areas, green manuring may mean loss of one season. However, this practice can be adopted for controlling weeds and addition of nutrients. In a study at Dehradun, sunnhemp green manuring reduced peak rates and volume of runoff and soil and nutrient loss. It improved soil fertility and stored more soil moisture for second crop of wheat as compared to natural fallow The yield of rainfed wheat was increased by about 25% (Narain et al., 1984)

The practice of green manuring may be considered as an alternative land use system for *kharif.* Green manuring can be viable and economical practice for growth of many crops Depending on soil moisture, application of fertilisers distinctly affect vegetative growth and the yield The crop canopy reduces runoff and soil loss and generated rootmass has beneficial effects on soil's physical condition

Residue management

Crop residues, which are generally left in the field after harvesting, can have tremendous influence on soil and water conservation. Crop residues act as a barrier for soil erosion and water runoff. In India, crop residues are usually fed to animals in the form of dry fodder and crop forage, so not much importance is placed on such aspects However, in developed countries, management of crop residues is an important aspect of soil and water conservation. Soil loss would reach unacceptable limits if stubble retention and crop residues are not practised.

Grasses

Inclusion of grasses in crop rotation has been found to reduce soil loss When the maize was grown in rotation with grasses, reduction of soil loss was reported (Moldenhauer et al , 1967). Even by maintaining crop and grass ratio, introduction of grasses for short duration in tobacco rotation was found superior to keeping the grass for a longer duration (Hudson and Jackson, 1959) In the first year 80% of erosion resistance is acquired by the soil through grasses In the second year, this reduces to 20% Various crop choices are available alongwith numerous grasses in different agro-climatic zones.

Vegetative hedges and buffers

In view of the ineffectiveness of mechanical bunds in uniform distribution of moisture in the interbund area and there high cost of construction and maintenance, alternative methods of erosion control are investigated In India mechanical bunds are virtually ineffective in stopping stray cattle entering into the fields Likewise, contour field bunds are detested and rejected by farmers in comparison to boundary bunds The vegetative hedges and buffers may be placed on existing field bunds, and in their absence, as such

(a) *Live hedges*: The main objective of raising live hedges in and around farm land is to protect soil and crops from wind and water erosion They are planted alongwith the corps, so their impact or influence on the crop must be ascertained and they must be properly interwoven with the farming operations They also need tending and after-care like any other crop The choice of shrubs and grasses to be used for live hedges depend on agro-climatic and edaphic factors Careful study of the available plants is essential and appropriate species may be selected But it is not justifiable to recommend only one species anywhere, say vetiver, as the failure rates may be high. In Jhabua, farmers have been traditionally using *Jatropha*, *Agave*, *Thuvar* and *Vetiver* in creating live hedges In certain areas, *Prosopis* has been used for these purposes. The thrust of watershed programme has been to promote these traditional practices and propagate them intensively.

(b) *Vegetative buffer strips*: Permanent strips of grass or shrubs may be used alone or alongwith mechanical conservation measures on gentle slopes. By providing a dense and continuous cover, they reduce soil loss and runoff resulting in deposition of silt. Over a period of time, the accumulated silt would create a bench terracing effect Indigenously, this is practised in many fields on high gradient to recover the land. Various grasses and shrubs, based upon the habitat and local preferences, may be used Unpalatable but economically useful grasses like *Cymbopogon citratus* or *Vetivera zizanoides* (*khus*) may also be grown. In certain villages, *Ipomea* is used as vegetative buffer barrier.

Grass strips are very popular version of live bund. A grass strip is a ribbon-like band of grass laid out on cultivated land along the contour Grass strips are about 1 m wide and are spaced at 1 m vertical interval. Protection of the grasses may be required all year long for the grasses to attain sufficient length, which may be useful to slow runoff and retain soil sediment They also replace soil physical structure by good infiltration on gentle slopes Grass strips are planned along the contour or along cutoff chains 1 m vertical spacing means that on a field with 3% slope, grasses will be 33 m apart, and on a 15% slope, they will be only 7 m apart Grass strips help to reduce runoff and to filter out sediments carried by runoff They are suitable, where the climate is not too dry, for dense grass development The grasses may be cut and used as livestock fodder Generally, local grasses should be selected as exotic grasses may not be adopted by the farmers Grass strips can be improved into alley cropping agro-forestry Care must be taken that the strips are not narrowed with every ploughing and a width of 1 m should always be maintained Due to multiplicity of agro-climatic regions in India, listing of suitable grasses/shrubs is not attempted here. The plant suitable for a vegetative barrier should have deep and aggressive roots (but without a tendency to spread), should be tough and hardy, should be pest-resistant and unpalatable to cattle, should have sterile flower (to prevent it from spreading) and should have little water requirement *Vetiver* grass is preferred in many parts of India as it tolerates a wide range of climatic and edaphic conditions, is simple to propagate and needs no maintenance It establishes a hedge within three growing seasons *Vetiver* is cheap to plant and can be planted by farmer without any expert advice

Agronomic measures have not become popular as compared to mechanical SWC methods even after realising that they are more advantageous Lack of knowledge about alternative species, suitable methods of establishment, management practices, maintenance and after-care have been the main reasons In areas with long dry periods, vegetative bunds especially grass strips, may have difficulties surviving and performing satisfactorily Holes created in vegetation of the bund by a heavy downpour in heavy rainfall area should be repaired immediately to avoid concentrated erosive water flow The loss of cultivable land and the risk of pests like rodents and diseases surviving in the better vegetative bunds are considered disadvantageous The agronomic measures on agricultural land should be extended with the help of agriculture department in watershed areas. These efforts would not only assist in SWC but also increase the production and productivity of agricultural plots

11

Erosion Control Measures on Agricultural Land

As large proportion of India is engaged in agriculture and most of the land under any watershed is agricultural land, a proper emphasis should be laid on engineering or mechanical erosion control measures. Land management and crop management (more appropriately called *engineering/mechanical measures* or *agronomic/biological measures)* control erosion on agricultural land. The mechanical measures consist of earth moving and land shaping practices, which are closely linked with the choice of land use and the land capability classification. Mechanical protection measures are the first line of defence against soil erosion and water runoff. Agronomic measures provide second line of defence. Mechanical measures are not in themselves constructive or productive but they are nearly always necessary and if required, they must come first (see Plate 27). After them, principles of correct land use and the techniques of agronomic conservation can be successfully applied. The two measures—mechanical and agronomic—are not alternative but are complementary. Both the measures should be compositely used.

Mechanical measures essentially consist of construction of mechanical barriers across the direction of the flow of water to retard or retain the runoff and thereby reduce soil and water losses. The erosion control measures must be simple and relatively inexpensive. With the increase in land slopes (most of which are complex), erosion control measures become more expensive and complicated with more emphasis on biological measures. Following principles must be kept in mind while planning various mechanical control measures:

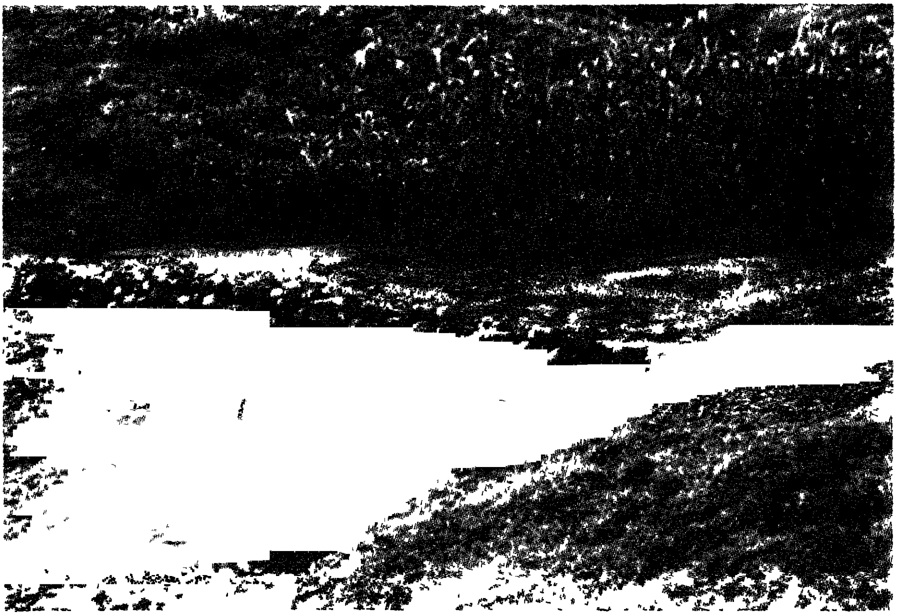
— increasing the time of concentration and thereby allowing more runoff water to be absorbed and held by the soil,

— intercepting a long slope into several short ones so as to maintain less than a critical velocity for the runoff water, and

— protection against damage owing to excessive runoff (Rama Rao, 1962).

Measures intended to control surface flow should aim at preventing the concentration and retarding the movement of free water over the ground. The mechanical measures, as practised in India, include contour cultivation, contour bunding, graded bunding, bench

Plate 27 *Boulder checks over gullies on agricultural plots stop further extension of gullies and reclaim land*



terracing, grade stabilisation structures, retention or detention reservoirs, grassed waterways, etc

To develop a scientific programme for land management, land is first classified in different groups known as 'land use capability classification' This classification is a systematic arrangement of different types of land to yield on a permanent basis without any degradation or erosion The most widely accepted land capability classification is made by the soil conservation service of the United States, Department of Agriculture(USDA) (see Chapter 4 for details)

Class I-IV land types are suitable for cultivation, but class V-VIII land types are unsuitable for any agricultural activity Sometimes, qualitative terms like very good, moderately good, fairly good, etc , are used to describe different soil capability classes They are based on land slope, soil depth, erosion hazards and workability of the soil

Contour cultivation

Cultivation operations are done across the slope, by keeping them on contour or nearly so. All field operations such as ploughing, seeding, interculture, etc , are done along the contours Ploughing produces ridges across the slope If ploughing is done on the slopes, then these ridges along the slopes may create furrows for water runoff, creating rill and gully erosion When the ploughing is done along the contours, then ridges along with the crops prevent the movement of water and soil In case of low rainfall, especially in arid and semi-arid conditions, contour farming helps to conserve moisture And in high rainfall areas, only a part of the water is conserved and the excess is drained in less damaging manner.

Soil erosion is also checked effectively The furrows that are developed due to contour cultivation, store large part of the rainfall and allow more time for infiltration Uniform distribution of moisture throughout the growth period results in increase in the crop yield Contour cultivation causes less wear and tear to mechanical parts of implements and less power is required to be exerted by men, animals and machines.

The effectiveness of contour cultivation in erosion control varies with slope, crop cover and soil texture. Maximum effectiveness of contour cultivation is on medium slopes and on deep permeable soils, which are either not prone to surface sealing effect or are protected with suitable cover to prevent surface sealing The relative effectiveness of contour cultivation decreases as the land slope becomes very flator very steep. The ratios of soil loss from contour-cultivated plots to those from up-and-down cultivated plots on different slope groups are shown in Table 11 1.

Table 11.1 *Effectiveness of contour cultivation on different land slope groups*

Slope group	*Ratio of soil loss from contour cultivation/up-and-down cultivation*
1%	0 6
2 to 7%	0 5
7 to 12%	0 6
18 to 24%	0 9

Adopted from Smith and Wischmeier, 1962

It can easily be deducted that contour cultivation is most effective on the moderate slopes of 2-7%, whereas both on flat or steep slopes the effectiveness is relatively less Contour cultivation is an important step in upstream flood control and reduces the peak flood as well as the total flood volume considerably On steep slopes and under conditions of high rainfall, contour cultivation may cause more harm than benefits. There may be breakage of ridges and as the water flows downwards cumulative flow increases This may result in serious damage and gully formation Therefore, under such situations, the contour farming should be supplemented by other measures like bunding or terracing Gradually, over a period of time, surface sealing takes place by fine particles and infiltration capacity decreases reducing the effectiveness of contouring

On undulated terrain having many depressions and ridges, contour cultivation is likely to be tedious. The water in the furrows collect in the depressions resulting in breaches of the furrows Land smoothening may be required to fill up such depressions Alternatively, depression grasses may be converted into grassed waterways, by keeping them under perennial grass cover

Studies have reported that contour cultivation is effective in reduction of runoff and prevention of soil erosion in the major soil groups of alluvial, black and deep lateritic soils of the country In the deep lateritic soils of the Nilgiris, due to contour cultivation, even on slopes as high as 33%, runoff was reduced by 44% and soil loss was reduced by 2% (Raghunath et al , 1967) Contour cultivation is distinctly superior to conventional up-and-down system of cultivation in both *kharif* and *rabi* crops (Rao and Rao, 1980)

Contour bunding

Contour bunding is a widely practised SWC measure on the agricultural lands throughout

India. It consists of constructing narrow based trapezoidal embankments (bunds) on contours to impound runoff water behind them, so that all the impounded water is absorbed gradually into the soil profile for crop use The contour bunds are carried out to reduce the length of the slope Contour bunding is generally recommended for low rainfall areas and for permeable soils upto slopes of about 6% in agricultural lands.

When the bunds are constructed along the contours with some minor deviation to adopt to field/practical situation, they are termed as *contour bunds*. If the bunds are constructed with some slope, they are called as *graded bunds*. If the bunds are constructed along the slope in between two side bunds to reduce the length of the contour bunds, they are known as *lateral bunds* Side bunds are constructed along the slope at the two sides of the contour bunds. *Supplemental bunds* are constructed between two contour bunds to limit the horizontal spacing of the contour bunds. Peripheral bunds are constructed along the field boundaries and may not conform to the contour.

The experiences, gained by Indian farmers regarding contour bunds in the past, have suggested that contour bunds could stand well only in shallow, medium and medium-deep soils. Deep black soils have tendency to crack in dry conditions Through these cracks flowing water in rainy days may cause breaches. Though there are numerous erosion problems in black cotton soils, contour bunding cannot be taken up in such soils with success.

The contour bunds can be either open-ended or hooked-up at the ends. If the ends are hooked-up, the intercepted water is made to impound on the upper edge till the water is absorbed into the soil With the open ends, the built up head of water causes the excess water to drain off slowly, after giving opportunity to infiltrate into the soil Bunds with open ends are used in low rainfall and moderately permeable soils, while bunds with hooked-up ends are adopted in the low rainfall areas with highly permeable soils

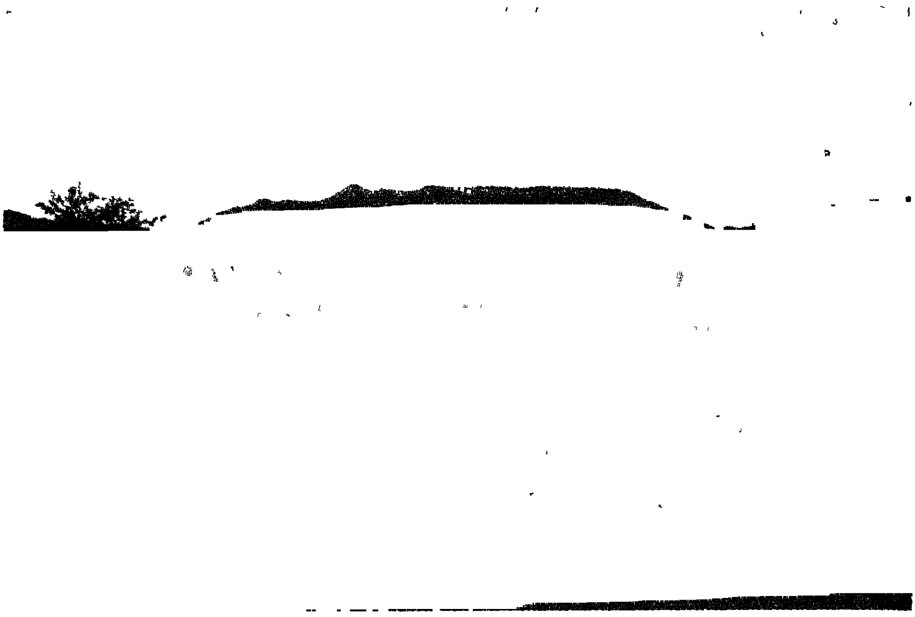
Planning of contour bunds

The planning of contour bunds should essentially consider the determination of (a) spacing between bunds, (b) cross-section of bunds, and (c) type and dimensions of the surplus system In India, contour bunding, as a popular SWC measure, is based on empirical formulae evolved from experience than on any strict scientific principles In almost all parts of India, self-made field bunds are usually boundary bunds (earmarking field boundaries) and are essentially not based on contours

Spacing between bunds is an important determinant As the water flows fast through a slope it attains erosive velocity The bunds should be ideally spaced in such a way so as to intercept the erosive velocity It should be kept in mind not to decrease spacing in such a way that it interferes with farming operations Spacing between bunds is commonly expressed in terms of the *vertical interval* (VI) It is defined as the difference in elevation between two similar points on two consecutive bunds The basic philosophy involved in calculating the spacing between two bunds is to keep the velocity of runoff below the critical value (see Plate 28)

C E Ramsay conducted experiments in sub-humid areas with good infiltration rates and developed a formula for calculation of vertical interval of contour bunds Vertical interval is usually expressed as a function of the percent slope (S) of the land The generalised form of the relationship being

Plate 28 *Field bunding should be taken as far as possible on contours Boulder reinforcement should be made wherever necessary*



$$VI = \left(\frac{s+b}{a}\right) \times 0.305$$

where:

VI = Vertical interval (in m)
S = Slope (in %)
a,b = Constant (specific to a particular region)

For soil with good infiltration rates, values of a and b are 3 and 2 respectively The formula becomes.

$$VI = \left(\frac{s+2}{3}\right) \times 0\ 305$$

Thus, the vertical interval in such soil conditions with 6 % slope would be 1 220 m And in low infiltration rate soil conditions the values of a and b are 4 and 2 respectively The formula becomes.

$$VI = \left(\frac{s+2}{4}\right) \times 0.305$$

Thus, the vertical interval in such soil conditions with 6% slope would be 1 068 m But, the above formula does not take into account soil and rainfall characteristics and its applicability cannot be generalised When the above formula is used for soils with high infiltration rate and with good conservation practices, 25% extra spacing can be used In soils of low infiltration capacity and minimal conservation measures, the spacing should be reduced by 15%. Similar adjustments are required for rainfall areas and *vice versa*. These problems of adjustments are taken care of in Cox's formula:

$$VI = (XS+Y) \times 0.305$$

where.

VI = Vertical interval (m)
X = rainfall factor
Y = infiltration and crop cover factor
S = slope (%)

Values of X and Y can be deducted from Tables 11.2 and 11.3.

Table 11.2 *Values of rainfall factor (X)*

Rainfall condition	*Annual rainfall*	*Value of X*
Scanty	< 625 mm	0.8
Moderate	625 to 875 mm	0.6
Heavy	> 875 mm	0.4

Table 11.3 *Values of soil infiltration and vegetative cover (Y)*

Soil type	*Crop cover during erosive rains*	*Value of Y*
Below average (clayey soil)	low coverage	1.0
Average or above average	good coverage	2.0
One factor favourable and another factor unfavourable for causing erosion	—	1.5

For example, in Jhabua which has scanty rainfall and below average soil and low crop cover, spacing of contour bunds on 6% slope would be

$$\{(0.6 \times 6)+1.5\} \times 0.305 = 1.56 \text{ m}$$

Gadkray and Rama Rao (1956), on the basis of their experience in former Bombay State, recommended the following spacings for contour bundings on different land slopes (Table 11.4).

Table 11.4 *Spacing of contour bunds*

Slope of land	*Vertical interval*	*Horizontal distance (approx.)*
0-1%	1.05m	105m
1-1.5%	1.20m	98m
1.5-2%	1.35m	75m
2-3%	1.50m	61m
3-4%	1.65m	52m
4-5%	1.80m	39m
5-6%	1.95m	36m

Beyond 6% land slope, contour bunding is not recommended. Bench terracing, though costly, is more effective.

Vertical spacing can be increased by 10% to provide better location, alignment or to avoid obstacles. In case a small strip is left in between the last bund and field boundary, the vertical fall may be distributed in all the bunds.

Cross-section of the contour bunds

A cross-section of the bund includes height and width. The usual shape of contour bund is a symmetrical trapezium in cross-section The cross-section of the contour bund should be decided after determining the spacing. It has following parameters:

(a) Bund height (h)
(b) Bottom width (b)
(c) Top width (t)
(d) Side slopes (s)

$$\text{Cross-sectional area} = \frac{(\text{bottom width} + \text{top width})}{2} \times \text{bund height}$$

$$CS = \left(\frac{b+t}{50}\right) \times h$$

The height of the bund is governed and determined by:

(a) depth of the water to be impounded,
(b) design depth of flow over the waste weir,
(c) freeboard,
(d) vertical interval between contour bunds, and
(e) dependence for maintenance on landowners.

The rate of infiltration influences the vertical interval and also the depth of water to be impounded. Sometimes, arbitrary depth of impounding of 0 30 m is considered for the design of bund cross-section. The soils with very poor infiltration rates may not need contour bunding

$$h = \left(\frac{R \times VI}{50}\right)$$

where

h = Depth of impounding near the bund (m)
R = 24 hour excess rainfall to be stored (cm)
VI = Vertical interval (m)

The above equation gives the depth of water that will be impounded immediately behind the bund To this depth, depth of flow over the waste weir and a freeboard of about 25% should be added 0 30 m is usually provided as depth flow over the outlet and 0.20 m is provided as freeboard This makes an overall height of 0 80 m After fixing the height, other parameters of the cross-section should be calculated. Generally, a minimum top width of 0 50 m is selected and the side slopes are decided from angle of repose of the soil Then, the base width of the bund is calculated The cross-section, thus obtained, should meet the minimum requirements from the seepage consideration. It is dependent on the head of water, soil permeability and side slope.

Generally, the height of the bund is kept at 0.30 m, the width of bund should be 0 50 m and the usual minimum side slope recommended is 5:1. In case of steeper slopes, where bunds are close to each other, the upper limit of side slope of 5 may be reduced to 4 1 (but in that case bunds have to be seeded with grasses). It is desirable to use a minimum cross-section of 1 sq m. The cross-section of bund may be varied for different kinds of soil, to take into account the side slope requirements and settlement In large farms, where tractor is used for farming operations, broad based contour bunding may be useful. The contour bunds may exclude more than 6% of the area from cultivation. Contour bund cross-sections recommended for Indian conditions are given in Table 11 5

Table 11.5 *Recommended contour bund sections for Indian conditions*

Soil type	*Top width*	*Bottom width*	*Height*	*Side slopes*	*Volume (cub m)*
Very shallow soils (soil layer)	0 45m	1 95m	0 75m	1 1	0 90
Shallow soils (soil layer 3"-9")	0 45m	2 55m	0 82m	1 25 1	1 21
Medium soils (soil layer 9"-18")	0 60m	3 12m	0 85m	1 5 1	1 56
Medium deep full soil (18" and more)	0 60m	4 25m	0 90m	2 1	2 18

Note In case of good maintenance and after-care, 10-15% less cross-section can be adopted

Alignment and construction of contour bunds

For the purpose of alignment and construction of contour bunds, a map showing area plan is necessary All natural features like field boundaries, gullies, streams etc. should be shown in the map. The area then may be divided into blocks of suitable size (say 50 ha) in which soil conservation programmes can be taken up at a time On these maps, the locations of the contour bunds are marked For drawing the position of the contour bunds on the map, at first level survey is conducted by taking a suitable grid distance. The contours can be drawn on the map at an interval of 0 30 m From the contour map, average slope of the land is calculated From slope, infiltration and rainfall characteristics, the vertical and horizontal intervals are calculated. Planning is started from the top of the watershed. Contour bunds are located on the map as per the calculated interval The position are then transferred on the field Modifications to eliminate the sharp curvatures and changes of existing field boundaries should be carried out Using direct contour method, the slope of the land is determined by taking fly levels Dumpy levels are taken from top to the bottom. The number of points with the same reading are located and the contour may be achieved (see Chapter 6 for details)

The construction of the bund should start on the upstream end and should proceed downstream The construction work can be done by manual labour, animal power or mechanical power If the ends of the contour bunds are hooked up, the ends of these side bunds are marked by deducting the height of hooking up from contour bund elevation. Usually, strict adherence to contour should be encouraged in the field. However, to avoid excessive curvatures in the bunds, which makes cultivation operations very difficult, the following deviations from strict contours may be permitted

— Not more than 15 cm deviation from strict contour, while cutting across a narrow ridge.

— Not more than 30 cm deviation from strict contour, in case of crossing a gully or depression.
— Deviation upto 1.5 m, in respect of a sharp narrow depression not exceeding 5 m in depth

After placing due consideration to the alignment of bunds, the construction should commence

1 The construction of contour bunds should start from the top of the catchment and should proceed downwards.
2 If the upper portion of the catchment is under a different land use and is not to be bunded, then diversion drains may have to be constructed to divert the runoff.
3. All bunds from top to bottom are constructed according to their full cross-section.
4. Intermediate bunds should not be kept unfinished or half finished
5 Soil for construction of the bunds should be taken from borrow pits of suitable size and numbers.
6. Borrow pits should be located on the upstream, in case of shallow soils and on either of the sides, in case of medium and deep soils.
7 Borrow pits so excavated should be of equal size with atleast a 3 m uniform bern between the bunds line and the borrow pits.
8. Berns between borrow pits should be kept as few as possible
9. Borrow pits should be located on the side ridge portion in case of a valley/gully and on the ridge itself in case of a ridge
10. The berns between borrows pits should be retained to avoid concentration of water towards depression. A cross-section of the bund includes height and width The usual shape of contour bund is a symmetrical trapezium in cross-section. The cross-section of the contour bund should be decided after determining the spacing It has following parameters:
11 The cross-section of the bund is to be checked by erecting templates at 150 m distances
12. Excessive removal of the soil should be avoided for construction of contour bunds
13 Ramps should be provided for the free passage.

In black soil, due to their low infiltration rates and excessive shrinking and swelling properties, contour bunding may cause waterlogging or cracks leading to breaches Graded bunds have the disadvantage that they drain out the precious water Thus, contour trenches/ditches may be taken up especially in black cotton soil area. Contour/conservation ditches are essentially an inverted form of a contour bund (sunken into the ground) with flatter upstream side slopes provided for safety against scouring by the incoming runoff They store most of the runoff and resist erosion thereby Also, the water stored in the ditches could also be utilised Thus, conservation ditches serve dual purpose of a terrace and a storage structure at the individual field level.

Loss of area due to contour bunding

The main reason behind rejection of contour bunding by small and marginal farmers is the area lost for cultivation by adopting them The actual area occupied by bund depends on the base width of the bunds, the slope and the vertical interval of bunds.

$$\text{Area lost (sq m) due bunding/ ha} = \frac{130 \times s \times b}{VI}$$

where:

S = Prevailing land slope (%)
VI = Vertical interval (m)
b = Base width of contour bund (m)

$$\text{\% area lost due bunding/ ha} = \frac{130 \times s \times b}{VI}$$

It can very easily be understood that the percent area lost due to contour bunding in small farm will be higher. Bunds can be used for growing grasses or crops This would compensate for area lost The number and length of the contour bund should be reduced, if existing boundary bunds could serve the purpose As such, excessive bunding should be avoided in shallow soils, black cotton soils and very low or high gradient terrains.

Computing of earthwork for bunding

It is important to estimate the earthwork required to be done Field bunds may result in heavy expenditures in a watershed area The earthwork for bunding includes the main contour bunds and the side and lateral bunds The total length of bunds per hectare·

$$\frac{1\,3 \times 100s}{VI}$$

(considering the CS of side and lateral bunds is equal to the main bund and length of side and lateral bunds to be 30% length of main contour bund)

$$\text{Cross-sectional area of bund} = \left(\frac{t \times b}{2}\right) \times h$$

$$\text{Total earthwork/ha} = \frac{(1\,3 \times 100s)}{VI} \times \frac{(t+b)}{2} \times h$$

$$\text{Expenditure on contour bounds/ha} = \text{Total earthwork/ha} \times 60$$

(if Rs 60 is the expenditure for 1 cu m. of earthwork)

In areas where bunds are already existing, the dimensions may be examined and necessary earthwork may be computed by multiplying length of existing bund and additional quantity required (required section-existing section)

Outlets of contour bunds

Runoff produced from some of the high intensity rainfall cannot be fully held in the catchment through construction of contour bunds Also, most of the crops require that excessive water should be drained from the field for their healthy growth and also prevent the leaching of plant nutrients below the root zone Thus, a surplussing arrangement or outlet should be provided to drain out excess water. Generally, the outlets or waste weirs are constructed at depressions with the crest at a height of 0 3 m above the contour. Successive outlets should not be located in a straight line.

(a) *Clear overfall weir.* It is made of a masonry wall of a suitably designed length and its crest at a height of about 0 3 m above the contour The two ends of the bunds should be properly pitched.

(b) *Channel weir* It is constructed of a stone wall underground with one end of the bund pitched. It is located at one end of the bund to prevent the nose of the bund getting breached. Dry rubbles may be used as stone work for the walls.

(c) *Pipe outlet*: It consists of a RCC or cast iron pipe of required diameter buried under the bund with downward slope. A vertical wall inlet of requisite height is provided on the upstream side. Generally, 15 cm diameter pipe is suitable for 3.5 ha catchment, 22 5 cm diameter for 5 ha and 30 cm diameter for 8 ha catchment

(d) *Ramp-cum-waste weir*: It consists of an earthen bund, generally with its top 22.5 cm above the contour level. It has a very flat side slope of 10.1 on both upstream and downstream sides If locally available, boulder pitching is done on the ramp. If rainfall conditions are favourable, the ramp should be pitched with grass.

(e) *Prefabricated structure outlet* It is made of reinforced cement concrete (1.2 4) at a suitable site Components like headwall, apron and two wings may be cast separately and can be installed at the location. It may also be dismantled, if it is not required at site

While designing waste weirs, a maximum intensity of rainfall of 25 mm per hour is assumed for bunds at the upper end of a catchment Bunds in lower reaches may require a reasonable allowance for flood absorption capacity. Following considerations should be kept in mind.

(i) Minimum length of a waste weir should be 1.2 m.
(ii) Any waste weir of clear overfall type should not be more than 6 m long
(iii) If the length of a waste weir is more than 4 m, a pillar halfway should be provided to strengthen the wall
(iv) Attempts should be made to remove runoff water as far as possible.
(v) When water is surplussed through a channel weir outside the catchment, that catchment should be excluded while arriving at cumulative catchment.
(vi) For a channel weir, 25% extra length over and above the recommended should be assumed.

Maintenance of bunds

Due to lack of maintenance much of the benefits are lost and in certain cases, degradation may bring even more damage. The neglect in maintenance of even a single contour bund would endanger the whole system in lower reaches. So, before rainfall, following repairs or maintenance works should be attended to

- firm plugging of all breaches,
- filling up of all sags in bunds,
- restoration to proper height and section,
- plugging of all rat holes,
- repairs of damaged outlets and bunds, and
- growing grasses and trees on bunds

Graded bunds

Construction of graded bunds is recommended for relatively higher rainfall areas (600 mm), where excess water is to be removed safely out of the fields to avoid water stagnation. Graded bunds are recommended even in areas of rainfall 500 mm, if the soils are highly impermeable (deep black soil) They are effectively narrow based versions of the channel terraces, where the design of the channel of a sufficient capacity, rather than the embankment (bunds), is important. In graded bunds, the water flows in a graded channel constructed on the upstream side of the bunds at non-erosive velocity and is let to safe outlets or grassed waterways. Channel portion of the graded bunds is also put under cultivation, whereas in case of graded waterways they are kept permanently under grass cover.

Designs

The design of graded bund includes determination of vertical interval (VI), grade and cross-section. As graded bunds are essentially meant for diverting the excess water from cropped lands, suitable outlets are required to safely remove the water so drained into them. The availability of water course with good vegetation strengthens the system. Short terraces draining into several outlets located in natural water courses are preferred to long terraces leading to one outlet If natural water courses are not in the vicinity, then artificial waterways are constructed at least two seasons in advance with vegetation and grasses Drop structures may be needed, when there is a sudden drop in the channel elevation and where velocities of the water would be too great to be borne by the grass cover The same principle, as used for determination of the vertical interval and horizontal spacing of contour bund, can also be used for graded bund In case the soil is very permeable with high infiltration capacity and good biological control measures are practised, the spacing of bund can be increased by 25% On the other hand, for a fine-textured soil without proper biological controls, the spacing may be reduced by about 15% from the calculated value The following gradient are suitable for different soils

Soil type	*Gradient (%)*
Clayey soils	0 1 to 0 2
Loamy soils	0 3 to 0 4
Sandy soils	0 5

Grade

Either a uniform or a variable grade is used for graded bunds For short bunds of 100 to 150 m length, uniform grade is used and for longer bunds, variable grade is recommended For most of the soils, grade can be in the range of 0 2 to 0 4% In case of long bunds of 400 m or so in a permeable soil, the grade can be 0% at the beginning and increases to maximum 0 5% at the tail end. For impervious soil, the grade at the beginning should be about 0.2% and increases to 0 4% at the tail end The basic aim is to provide sufficient velocity of water so that an economical cross-section of channel can be obtained and at the same time the velocity should be non-erosive The grade should generally change after every 100 m length Short bunds of 100 to 200 m with channels (terrace) reduce the maintenance problems. For short terraces, uniform grade may be given and for large terraces, variable grades should be considered.

Cross-section

The cross-section of the bund should be sufficient for stability, highest flood level should be below the top of the bund and the seepage line should lie below the toe of the bund on the downstream side. The sides should be flatter to permit easy cultivation of the channel area without damaging the shape. Side slopes should not be steeper than 5.1. The shape and size (CS area) of the channel remains the same throughout the length of the bund. It is only the gradient which is varied to take care of the increasing quality of runoff as the length increases. The velocity in the channel should not exceed the safe velocity (non-erodible velocity).

Generally a top width of 50 cm is used, although it may vary from 30 to 90 cm for various heights of the bund. The height can be from 50 to 80 cm. Table 11 6 shows the dimensions of a typical trapezoidal shaped bund. The stable side slope depends upon the type of soil. For clayey soil it may be as steep as 1:1, for loamy soil 1.5 1 and for sandy soil it is increased to 2:1. The seepage line has horizontal to vertical slope of 3.1, 5 1 and 6 1 for clayey, sandy loam and sandy soil respectively The base width of the bund should, therefore, be designed using this criteria and the depth of flow

Table 11.6 *Typical dimensions of trapezoidal shaped graded bund*

Height (cm)	*Top width (cm)*	*Bottom width (m)*	*Cross section (sq m)*
55	50	2 25	0 75
80	50	2 50	1 00
80	50	2 60	1 25
80	50	3 50	1 50

In case a channel is constructed in combination with the bund, the channel should have sufficient capacity to carry the excess runoff with non-erosive velocity The non-erosive velocity ranges from 50 to 75 cm for soils varying from sandy to clayey types. Generally, a cross-section of 1 sq m with a depth of about 45 cm serves the purpose in most of the cases The channel may be designed for parabolic shape, as it finally assumes that shape although originally constructed as trapezoidal

Construction

As in contour bunds, the alignment can first be made on a contour map and then transferred to the field They can also be aligned directly in the field. Before deciding the alignment of graded bunds, the location of the outlet and the grassed waterway should be finalised

The reduced level (RL) of the outlet point of the topmost bund is determined The distance along the contour is measured in a step of about 25 m and the elevation of the alignment is increased to provide the necessary grade In case, a variable grade has to be provided, the same procedure will work except that the rise in level at different steps will be proportional to the grade The outlet elevation of the second bund is obtained by deducting the vertical interval from the RL of the outlet of the first bund (see Chapter 6 for more details).

The construction method of graded bund is same as that of contour bund. If manual labour is easily available, it can be used in construction of the bund Before that the soil should be loosened by ploughing. If a channel-cum-bund is constructed then the soil for bund should be obtained from the channel Otherwise, the soil should be scraped from both sides of the bund for its formation.

Velocity more than 0.50 m in sandy soils and 0 65 m in erosion-resistant soils is not safe. Let L be the length of the main bund per hectare and K be the critical length of bunds and assuming that the outlets receive water from both sides. Then:

$$\text{Number of outlets required per ha} = \frac{L}{2K}$$

Maintenance

The graded bund should be inspected after heavy rainfall. The undue settlement in the bund, the places of depression, excessive grade in the channel causing scouring and rill formations and excessive interbund erosion should be inspected Levelling, cutting or filling would eliminate these defects. For maintenance, the dead furrow should always be in the centre of the channel and the back furrow at the top of the ridge Proper farming practices protect the cross-section from being reduced and help in constant build-up and easing the side slopes Perpendicular crossing of the bund should be avoided The contour bund may be planted with suitable grasses or vegetation. Proper and timely maintenance of grassed waterways are essential. Most of the graded bunding in India has failed due to the failure of the grassed waterways.

Advantages and disadvantages

(a) Advantages

1 They drain out excess water safely and efficiently and eliminate water stagnation.
2. The cross-section of the bund is small; costs are also low
3 The excess water is drained out into protected waterways and not onto lower agricultural areas Graded bunds provide better protection to the interterrace treatment such as contour cultivation, strip cropping, etc

(b) Disadvantages

1 It requires grassed waterways (for diversion of excess water) which requires construction and maintenance with the cooperation of several farmers .
2. Seeds and seedlings in the channels in lower reaches, may get washed away after heavy rainfall
3. Weeds collected in the lower portion of the channel may propagate in the fields due to availability of moisture and may cause menace with the agricultural crops.
4 Graded bunds may cut across many holdings They require confidence and cooperation of the farmers
5 Water once removed from a field cannot be brought back easily, unless stored in ponds near to the individual fields

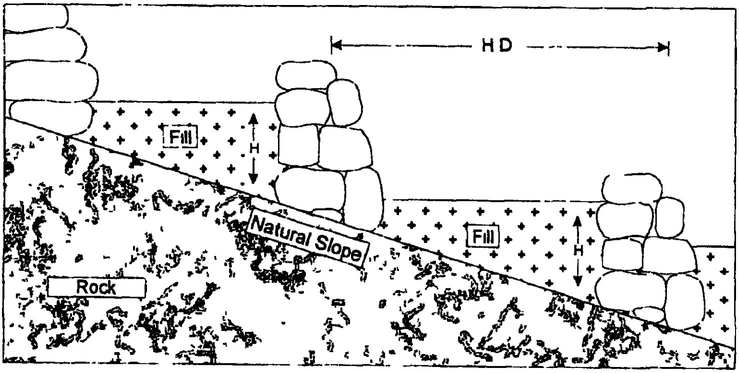
6. Heavy rainfall may cause heavy scouring in the channel.

Bench terracing

Bench terracing is a mechanical method by which land surface is modified through construction of ridges, channels or change of land slope for control of soil erosion and moisture conservation. This practice is prevalent on the steep hill slopes (where agriculture has replaced forests and grasslands by human intervention). In the steep hill slopes, mere reduction of slope length by contour bunding may not be able to reduce the intensity of scouring action of runoff water, it may be essential to modify the degree of slope. By bench terracing, the original ground is converted into level step-like fields constructed by cutting and filling. This measure reduces the slope considerably. It also helps in the uniform distribution of soil moisture, retention of soil and manure and also in the better application of irrigation water. *Bench terracing is costly SWC measure and should be used only where less expensive measures have failed to provide requisite control and protection.*

Terracing is an excellent SWC measure which helps in cultivation of crops on sloping land on a sustainable basis. They prevent formation of gullies and also help to reclaim gullied lands. Terracing should be supported by proper agronomical practices like contour cultivation, rotational cropping, etc. In rainfed areas, bench terracing is normally practised in 16-35% slope range (Figures 11.1 and 11.2).

Figure 11.1 *Sketch of bench terrace constructed by fill*

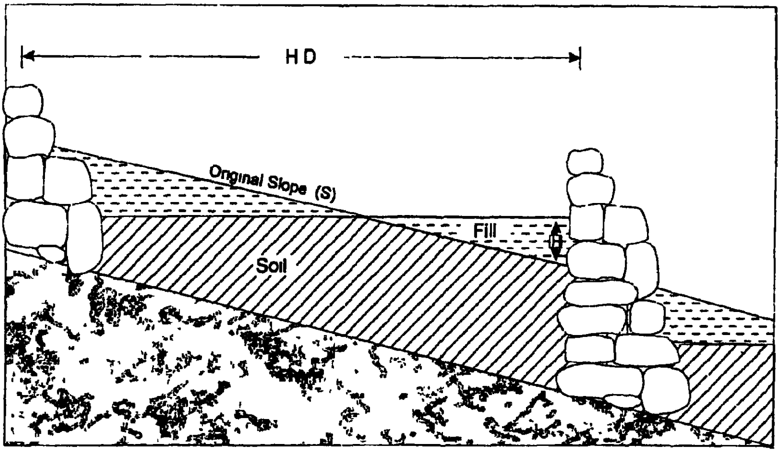


The bench terrace essentially consists of four components, namely, (i) riser, (ii) outlet channel, (iii) platform, and (iv) shoulder bund The riser is in vertical wall at the upstream end of the strip of land converted to bench terrace. The outlet channel can be located either at the upstream or at the downstream end depending upon the rainfall and soil conditions. Platform is the level or nearly level strip obtained by terracing and crop is grown in this zone. Shoulder bund helps to retain the rainfall in the terraced area.

Types of bench terraces

Depending upon slopes (i) level bench terrace, (ii) outward sloping bench terrace, (iii) in-

Figure 11.2 *Sketch of bench terrace constructed by excavation*



ward sloping bench terrace, (iv) California type terrace, (v)Tati terrace, (vi) conservation bench terrace etc. (Figure 11.3)

(a) *Level bench terrace* They are also known as table-top or paddy terraces. They are generally used in paddy cultivation. On a land of very mild slope, level bench terrace is constructed to facilitate paddy cultivation The level type is suitable in areas with medium rainfall and permeable soils

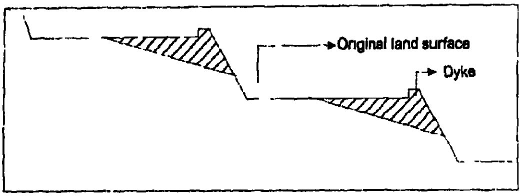
(b) *Outward sloping bench terrace*: In areas of low rainfall or shallow soil depth, this type is suitable. The existing steep slope can be reduced to a mild slope to reduce soil erosion, conserve some moisture and grow crops other than transplanted paddy. In case levelling is done in phases, this may be considered as a step towards achieving a level or inward sloping terrace. The surplus runoff water should be safely disposed of through the provision of a graded channel. In places of low rainfall or shallow soils, such bench terraces reduce the existing steep slope to a mild slope (say from 10% to 4%). Bench terraces constructed on soils with poor permeability, graded channel has to be provided at the lower end to safely dispose of surplus water in a waterway. In very permeable soils, strong bunds with spillway arrangement may be sufficient

(c) *Inward sloping bench terrace*: In high rainfall areas with steep slopes these type of terraces may be used. They have a drain on the inner side which is provided with a suitable grade along the length to convey the excess water to one side Vegetated waterway is used to dispose off the water from such drains These are widely used in the Nilgiri hills of Tamil Nadu as well as on steep Himalayan slopes in Himachal Pradesh and north-east hills

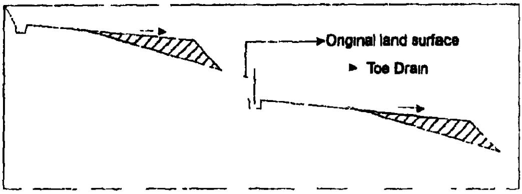
(d) *California type terrace*. This is also known as *puertorican* type terrace. At first, a vegetative or mechanical barrier is established along the contour Then, the soil is ploughed and pushed downward gradually during tillage operations every year Thus, the terrace is developed slowly over a number of years. But, this may also result into reduction of productive soil depth and hence leads to loss of crop yields, unless the

Figure 11.3 *Types of bench terraces*

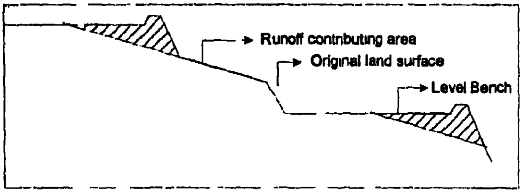
1 Level Bench Terraces



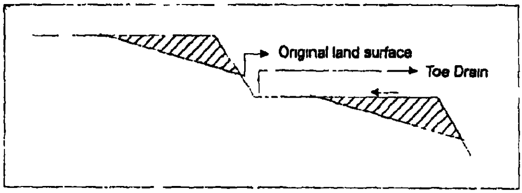
2 Outward Sloping Terraces



3 Conservation Bench Terraces



4 Reverse Sloping Terraces



fertility is reconstituted by the use of manures, fertilisers and micro-nutrients. Additionally, mechanical or vegetative barriers are kept on the original hill slopes at convenient distance and the terraces are gradually formed. These barriers check the soil, so moved, from being washed downwards

(e) *Tati terrace*· The Tati terrace was first adopted in Tati village near Chandwa in Palamau district of Bihar. On land with slope upto 3% and where contour bunds are not possible due to existing field boundaries, rectangular retention terraces known as Tati terraces are found to be useful Bunds are constructed on all or at least three sides following the revenue boundary, so that water is stored and some levelling is done. Outlet is provided at one end and a vertical interval of about 60 cm is maintained.

Designs of bench terraces

Terrace design is influenced by the conditions of soil depth, slope, rainfall, farming practices, etc The design includes· (i) terrace spacing, (ii) terrace grade and length, and (iii) terrace cross-section.

Puertorican-type terraces with vegetative (grass) and mechanical (earthen) barriers could be developed within 2-4 years For better stability and support for earthen bunds, stones can be used with advantage, if locally available Developing a bench behind a pre-established grass barrier would be cheap and will cause least disturbance of soil during construction and without effecting soil fertility (Poornachandran et at, 1970) Puertorican terraces with vegetative barriers, though economical produce lesser yield due to effect of vegetative barriers on crop with maximum reduction in rows close to the barrier In case of winter crops these effects were not pronounced (Jaya Kumar et al, 1979)

Terrace spacing

It is normally expressed in the form of vertical interval at which terraces are constructed Terrace spacing depends upon factors like slope, grade, soil, surface conditions and agriculture practices The VI affects the depth of cutting and the height of shoulder bund and hence affects the total height of vertical drops It is important to keep enough space on the terraces so as to enable convenient and economic agriculture operations. Following formula may be used to calculate VI

$$VI = \frac{w \times s}{(100 - s)} \text{ for riser with side slope 1 1}$$

$$VI = \frac{2 \times w \times s}{(200 - s)} \text{ for riser with side slope 0 5 1}$$

where

VI = Vertical interval
W = Width of terrace
S = Slope

Step-I Assess the maximum depth of productive soil range (D). More is the value of D, more cutting would be possible in preparing bench terraces

Step-II Assess the maximum admissible/permissible cutting (d), for the desired land slope and crops to be grown The convenient width of the terrace should be kept in mind

Step-III: Assess the width of the terrace (W), for the given slope (S) by using the formula, W=(2ooxd)/S where W and d are in metres and S is in percent. Finally, the VI can easily be estimated. The formula suggests that for the given slope, the greater the VI the greater would be the width.

Terrace gradient

In the case of high rainfall and less permeable soil, excess runoff should be disposed off by providing a suitable gradient to the terrace. Suitable gradient assures quick disposal of the excess water Following steps may be followed to estimate optimal gradient:

Step-I. Assess and calculate the peak rate of runoff (cu m) from the bench terraces using the rational formula, Q = (CIA/360)

Step-II. The area drained, A(ha) can be calculated by the formula, A = LW/10,000; where L = length of terrace (m), and W= average width of terrace (m)

Step-III: Assess non-erosive velocity (permissible velocity of flow) for the specific soil conditions, which can be approximately calculated from the standard table.

Step-IV· Assess the approximate area of cross-section of the channel by using the following formula:

$$A = \frac{V}{Q}$$

where

V = Permissible velocity

Q = Peak rate of runoff

Step-V: Assess hydraulic radius (R) from the cross-section obtained in step IV Mannings' formula may be used to compute the gradient of the channel:

$$V = \frac{1}{n} \times R^{2/3} \times s^{1/2}$$

where:

V = Permissible velocity

n = Mannings roughness coefficient

R = Hydraulic radius

S = Slope (in fraction)

Step-VI The value of S is rounded off and V is recalculated It should be less than the maximum non-erosive velocity. If it is not, then the cross-section should be changed and the calculation repeated Usually, a slope of upto 0 75% has been found to be safe under most of the conditions. The inner edges of the terrace should be lower than the outer edges in the gradient of about 0 5% The difference in levels of terrace between outer edge and inner edge of the terrace - DL (m) (also see Table 11 7) can be calculated from the following formula

$$DL = \frac{D}{2} \times \{0\ 10 = (0\ 005 \times w)\}$$

where

D = vertical drop (m)

W = Width of terrace (m)

0.10 and 0.005 are shrinkage and longitudinal factors.

Table 11.7 *Values of DL for terracing in normal areas*

D	*W*	*DL*
0 30m	30m	0 17m
0 45m	25m	0 14m
0 60m	20m	0 13m
0 75m	20m	0 14m
0 90m	20m	0 15m
1 00	20m	0 15m
1 25	15m	0 14m
1 50	15m	0 15m

Terrace cross-section

The construction of a bench terrace should be done in such a way that the earthwork excavated from the upper half is deposited over the lower slope The deposited earthwork forms an embankment on the edges So, care must be taken to secure it. This may be effectively done by clearing the surface of all vegetation and by providing suitable key trenches The volume of cut (excavated earthwork) should be equal to the volume of fill Precautions should also be taken up to provide suitable side slope in cutting and embankment, so that it may be well-seated on this slope The height of the embankment should be increased regularly and sufficiently to provide for shrinkage of soils It should be properly consolidated. The cross-section of the shoulder bunds, along the edge of the terrace should also be suitably designed, to be stable against slipping and overtopping Shoulder bunds are usually 0 2-0 3 m high with bottom width of 0 80 m and side slopes of 1:1 Protection to the risers of the terrace may be ensured by establishing grasses over them and by providing stone pitching, depending upon the availability of material. Grasses like *Dicanthium, Eragrostis curvula, Paspalum dilatatum*, etc , may be used for this purpose Local grasses may also be grown for stability.

Alignment of terraces

The convenience for cultivation and the existing field boundaries should be primarily and seriously considered for aligning bench terraces The alignment should be such that convenient and economic-viable agriculture is possible on the terrace width. Proper adjustments and negotiations must be ensured to encompass already existing field boundaries All sharp and inconvenient curves should be eased out deviating from the contour, if necessary Acute bunds and straight junctions should also be avoided as far as possible The deviations may be restrained to, say 0 3 m, while negotiating depressions or sharp bends In any case, this should not be more than 0 6 m.

Terrace execution

The proper alignment should be worked out, keeping local conditions in mind, the contour lines should be actually marked on the field by using method of direct contouring After that, seat of the embankment should be prepared by ploughing and clearing all vegetations and roots. Key trenches have to be excavated in certain sloping terrains as well The excavation is usually commenced from the middle and excavated earth is gradually pushed towards the lower slope, until the desired level is achieved. The required gradient may be ascertained by dumpy level and final scrapping and levelling can be carried out The proper sections of shoulder bunds with appropriate height should be carried out manually. Side slopes should be carefully maintained. Grasses may be planted on the side slopes and shoulder bunds to give stability. Usually the construction of bench terrace is taken up from top to bottom. After levelling the first terrace, the top soil of the higher adjoining aligned bench terrace should be pushed down to the lower terrace Thus, all terraces will have topsoil of the adjoining above terraces and only the top terrace will be without topsoil. It should always be kept in mind that the process of bench terracing is very costly. Hence, additional earthwork should only be considered when it is very essential. For example, if 0.30 m of soil is scrapped off, the additional earthwork per hectare will be 10000x0.30=3000 cu m.

Computation of earthwork for bench terracing

The earthwork per ha is computed by using the following formula

$$E \text{ (earthwork per ha) } \frac{100w \times s}{8} \text{ (for vertical cut)}$$

$$E = \frac{100w \times s}{8} - \frac{500n}{w}$$

where:

W = Width of terrace(m)
S = Land slope (%)
n = Slope
Area available for cultivation = 100 (100-ns) of land slope
Area lost due to benching = 100 x n x s
Percentage of area lost in benching = n x s
Number of terrace outlet/ha = L/2K

where·

L = Total length of terrace/ha
K = Critical length of terrace (m)

The actual cost of bench terracing depends upon condition of soil and sub-soil, land surface, vegetation cover, undulation, slope of the area, specification of bench terrace, alignment and terrace outlet. The principal item that affects cost of bench terracing/ha is the total quantity of earthwork involved.

Bench terraces with stone walls

Such terraces can be taken in areas where stones are easily available in adequate quantities close to the site. Bench terraces with stone walls may be used for annual crop cultivation and perennial tree plantations. Following formulae may be used to detect horizontal intervals between bench terrace with retaining stone walls and other important considerations:

(i) $HI = 100 \times H/S$

where
HI = Horizontal distance (m)
H = Height of retaining wall (m)
S = Slope (m/100m)

(This formula applies only to those bench terraces constructed by building a retaining wall and filling it with soil brought in from outside. This method is expensive and used only where the soil depth is insufficient).

(ii) $HI = (H1 + H2)/S \times 100$

where
$H1$ = Depth of excavation in upper part of terrace (m)
$H2$ = Height of fill in the lower part of terrace (m)
S = Slope (m/100m)

(iii) $HI = 2\,(D1 - D2)/(S1 - S2)$

where
HI = Horizontal distance (m)
$D1$ = Present depth of soil on the area (m)
$D2$ = Minimum soil depth required by the crop(m)
$S1$ = Percent slope (m/m)
$S2$ = Presumed stable slope (m/m)

The retaining wall should be constructed from stones collected on the spot. Usually, low and close retaining walls are preferable to high walls set far apart. Small capacity furrows to conduct small quantities of water may be opened at the foot of every retaining wall These furrows should have continuous longitudinal gradient, so furrows may be designed to run on graded strips Alternatively, runoff from such terrace may be diverted from the cultivation furrows and retaining walls into deep, narrow ditches made of stone, concrete or earth Wide shallow vegetated waterways should be avoided Two methods may be followed to provide protection to bench terrace of stone walls from quick runoff water They are as under

(a) *Combining vegetated waterways with drop structure of stone* The drop structures in the waterways, which may be considered as an appendage of the retaining walls, have height lower than that of the wall The height may be assessed from the amount of flow in the waterway Places where the retaining walls are set far apart, it may be necessary to construct additional drops in the waterways The area of the waterway may be sown with perennial grasses

(b) *Paving the waterways with stone* It is a very good option but it is very costly The waterways may be used as a field track

Stone walls should have a width of around 0 3 m on the top and around 0 8 m at the bottom, if they are 1 m high. The foundation should at least be 0.3 m. A length of around 1 m of terrace will require 0.55 cu m of stones. One skilled or semiskilled labour should be able to raise around 2 m of wall on the terrace. The reshaping of the stones may also be required for stable structure.

Conservation bench terraces

In the conservation bench terrace (CBT), the terrace width is divided into two parts—the *runoff part* and the *bench part* The upper part is the runoff part which is left undisturbed and contributes runoff water. The lower part is the bench part which receives the runoff water The bench part is levelled by cut-and-fill method and generally a maximum depth of cut of 25 cm is used. A part of the excavated soil is used to construct two edge bunds and the laterals. The topsoil is spread in the runoff part to smoothen the land surface to a uniform slope. At the junction of the runoff and bench part a transition with a slope of 1.5.1 is provided. Grass turfing is provided to prevent scouring of this part.

Depending upon the land slope, the CBT is divided into different width ratios. For a slope range of 0.25-1%, the ratio of width of runoff part and bench part is 3.1 For slope range of 1-2%, it is changed to 2.5:1. For a slope range of 2-4% the ratio may be 2:1. The ratio of runoff part to bench part varied in the range of 1:1 to 3·1 and yield improved in the range of 18-36%. In India, CBTs have been successfully used at Belary, Kota, Hazaribagh, Doon Valley and Midnapore. In red soil of Midnapore with a slope of 1 5% and bunding at a spacing of 40 m, produced a maximum of 72% runoff Intercropping with maize and *kalai* (2:5) reduced the runoff to 27%. In CBT system this runoff could be impounded in the bench part for growing paddy.

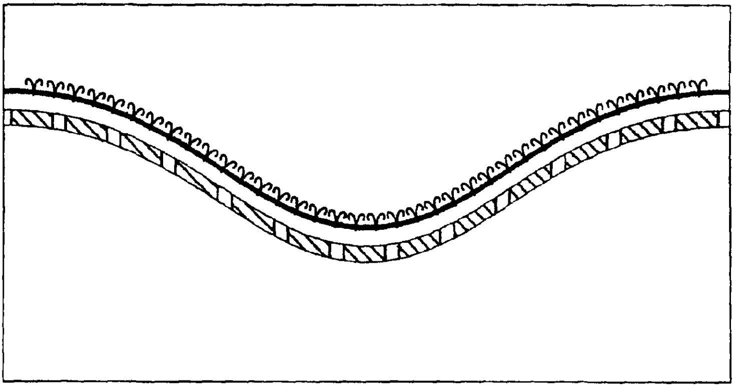
The Ootacamund Research Centre arrived at the conclusion that bench terracing reduces runoff by 50% and soil loss by 98% of that from fields under potato crop cultivated up-and-down the slope. It also provided better moisture conditions throughout the year (Raghunath et al , 1977). It has also been observed in another study that length of bench terraces did not influence the runoff, soil loss and the yield of crop. However, for better moisture distribution along the length, it was found desirable to restrict the terrace length to 100 m (Das et al., 1967).

Grassed waterways

Grassed waterways are outlets for channel type of terrace to conduct the surplus waters safely into natural drainage courses without causing gullying. A waterway is natural or artificial channel discharging concentrated runoff from slopes, terrace system or any other land surface safely It is an important soil conservation practice, since it discharges water safely and thereby protects the land against rills and gullies Grassed waterway becomes essential where suitable natural drainage-way is not available to drain-off excess water from agricultural fields. Usually, the most ideal location for a grassed waterway is a natural depression or drainage line, where the slope is the steepest in the watershed Natural land slopes result in maximum flows in these natural depressions Moisture conditions are usually most favourable for vegetative growth in them. They may also be artificially constructed and should be located near the field boundaries to avoid hindrances in field operations Grassed waterways should ideally be constructed one or two seasons preceding the year of construction of channel terraces and diversions. This is done so that the waterways have excellent vegetative growth at the time excess runoff is released into them (Figure 11.4). Grassed waterways are generally constructed in three slopes viz. triangular, trapezoidal and parabolic. Where natural depressions are shaped into water courses, a parabolic cross-section is preferred as it resembles natural channels. The side slopes are kept very flat, e.g., 8:1 or 12:1 so as the crossing of farm implements is not hindered. Only difference between a grassed waterway and a diversion is that a diversion has comparatively lesser grade whereas the grassed waterway is laid along the slope The grassed waterways serve the following functions·

(i) outlets for diversions and terraces,
(ii) outlets for farm ponds,
(iii) outlets for emergency spillways,
(iv) dispose of water collected by ditches or discharge through culverts, and
(v) carry runoff from natural drains and prevent formation of gullies.

Figure 11.4 *Cross-section of a grassed waterway*



Planning and design

Longitudinal and cross-section surveys along the proposed course of the waterway may be conducted. This will help in dividing the waterway into reaches of approximately uniform slope, shape and size. Identification and assessment of soil characteristics, land use, vegetative patterns and topography classification would help in calculating the runoff coefficient (C) The peak rate of runoff (Q) for a 10-year recurrence interval for an area is worked out by using the rational formula

$$Q= C \times I \times A/360$$

The permissible velocity for a particular soil type and vegetation (grass)lining may be decided

— 0 9 m/sec(where sparse coverage would be possible)
— 0 9-1 2 m/sec (for vegetation established by seeding)

- 1 2-1.5 m/sec(where vigorous and dense soil may be established with ease)
- 1.5-1.8 m/sec (for well-established sod of good quality).
- 1 8-2 1 m/sec (for well-established sod of good quality and under conditions where flow can not be handled at lower velocity)

The cross-sectional area of the proposed channel may be worked out using the formula·

$$A = Q/V$$

where:

A = Cross-sectional area
Q = Peak rate of runoff
V = Permissible or non-erodible velocity

Suitable dimensions of the channel can be worked out by trial and error The capacity of the channel cross-section to carry the estimated peak discharge may be worked out using Manning's formula·

$$Q = \frac{A \times R^{2/3} \times s^{1/2}}{n}$$

where

A= Cross-sectional area
R= Hydraulic radius
S= Slope in fraction
n= Manning's roughness co-efficient (usually 0.035 or 0 04 for freshly constructed earthen channel)

A freeboard of 20% extra depth, subject to a minimum depth of 0.15 m is added to the computed value to take care of any higher flood of greater recurrence interval There may be retardation in speed due to the vegetation, so provision for extra depth may be ensured

Construction

For the waterways located in a natural drainage way with negligible gullying, the shaping is a simple process If the watercourse is to be established on any existent gully, then amount of earthwork involved will be more as gully is required to be filled and then shaped to establish waterway with required cross-section The alignment may have to be changed by negotiating sharp bends and curvatures Application of lime and fertiliser may be restored for quick establishment of vegetation A mixture of quick growing annuals for temporary control and hardy perennials for permanent protection may be used The seeding should be done in the same direction as the flow of water

The cross-section (A) and wetted perimeter (P) and top width (T) for different shape waterways can be calculated from formulae given in standard SWC textbooks

Waterways should not be used as stock trails, cart-trucks(commonly practised) or as pastures Sediment collection in watercourse should be periodically cleared The vegetation in waterways should be periodically trimmed and unnecessary bushes and shrubs should be removed and cleared

Diversion drains

These are used to divert the runoff above the gully and to allow it to flow at a non-erosive velocity to a suitably protected outlet A diversion is a graded channel of ditch, somewhat similar to a graded channel terrace, designed to intercept surface runoff and convey it safely to an outlet or waterway Diversions are particularly adopted to areas already covered with trees or grasses because the channels below these areas are not likely to be silted up Sometimes, they are located below cultivated fields, then a permanent filter strip of close-growing vegetation may be placed above the channel to catch the silt carried in the runoff from the fields These filter strips should have a minimum width of 15 cm. Usually, these diversion drains are planned so as all the conservation structures lower down in the cultivated area would not be damaged from the water coming from upland non-agricultural areas If the diversion drains are ineffective, then the water released from the system is almost certain to breach all the structures in the agricultural areas They are also provided to divert the storm runoff away from the gullies Diversion drains are provided across the slopes on slight gradients. Their capacity is calculated and designed for a 10-year recurrence interval storm Generally, a side slope of 4 1 is maintained The design, construction and maintenance of diversion channels are similar to grassed waterways The diversion drain should be set back from the head of the gully at a minimum distance of three times the height of the gully head overfall It is usually larger in capacity and may have a steeper gradient than that of a terrace

Surplussing structures

Purpose and types

Outlet or surplussing structures are constructed to drain away excess runoff water These structures are important to protect contour bunds from breaches and avoid damage to dryland crops from water stagnation These structures are usually constructed in the lowest spaces in an agricultural holding If the area to be drained is more than 4 ha. then there is a need for construction of masonry weirs in the bund Waste weirs are located at depressions with the crest of their body walls constructed at 0 3 m above the contour These should be constructed in a staggered fashion so that they will not cause gullying of the field in between the waste weirs (Figure 11 5)

(a) *Channel weir* A channel weir is provided at one end of the bund to prevent the nose of the bund from getting breached and the fill of the channel weir is kept 0 30 m above the contour level of the bund

(b) *Clear overfall stone weir* It comprises a masonry wall of a designed length constructed at a suitable place in the bund and the two ends of the bunds are stone pitched A clear overfall weir should be provided along the contour bund, usually with its crest 0 30 m above contour, suitable for crops like sorghum *(jowar)* and pearl millet *(bajra)*

(c) *Cut outlet* It is a channel weir and is cut as an ordinary channel about 1 75 m away from the end of the bund with its fill kept 0 30 m above contour level It has an approach and a tail channel to give runoff water proper entrance to and exit from the weir Usually, such cut outlets are proposed only in hard material

(d) *Pipe outlet* A pipe outlet comprises a pipe discharging surplus water It consists of a huge pipe of required diameter A 15 cm diameter pipe is suitable for 4 ha catchment,

Figure 11.5 *Examples of small weirs*

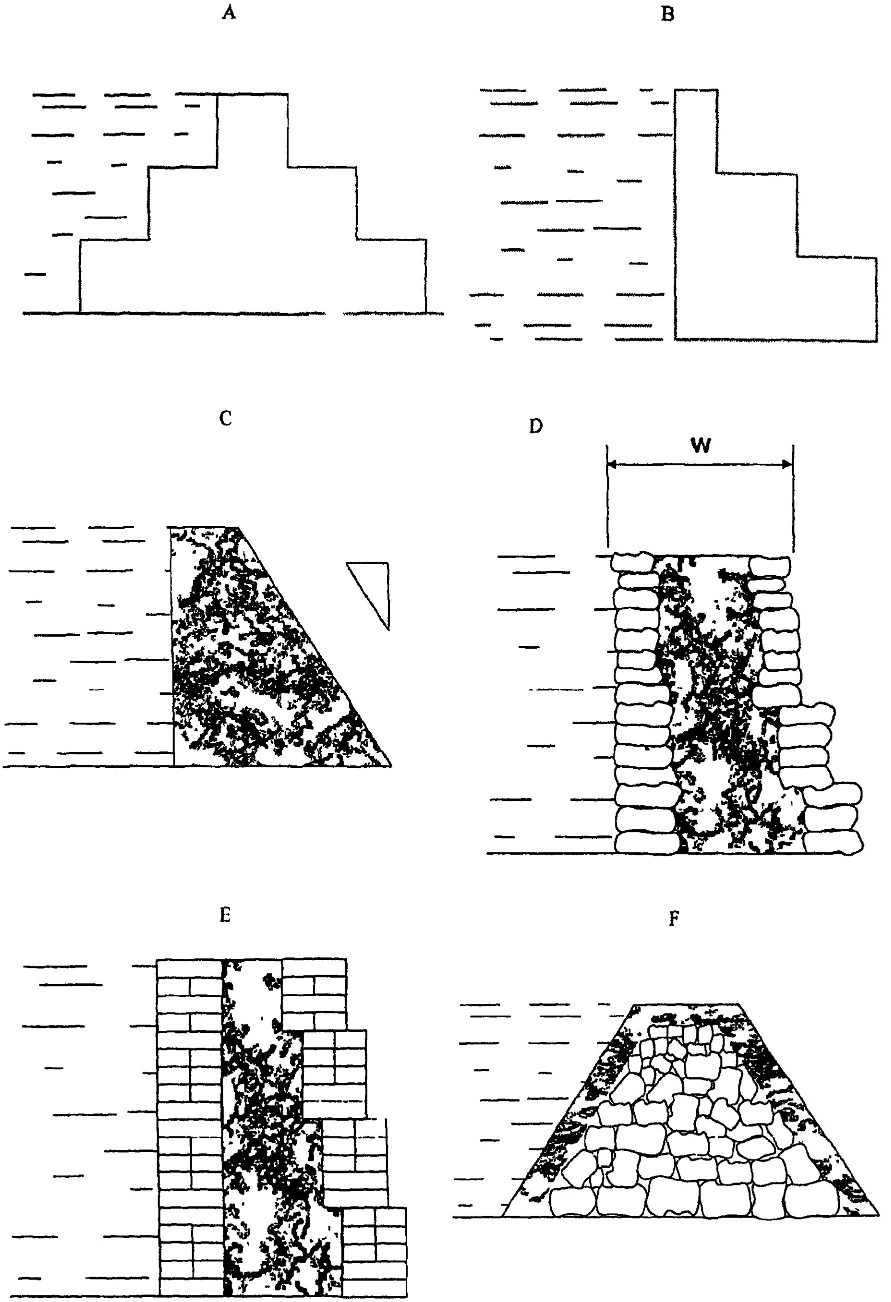
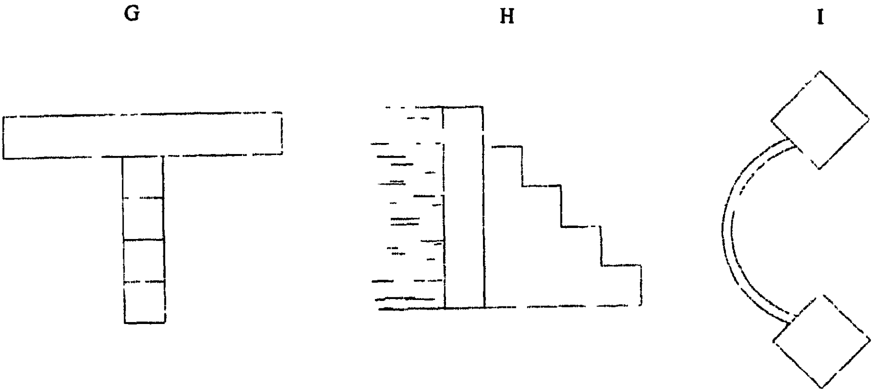


Figure 11.5 *Examples of small weirs (contd)*



22 5 cm pipe up to 7 ha and 3 cm pipe can work upto 12 ha

(e) *Ramp-cum-waste weirs* They are of temporary nature and consist simply of an earth bund with its top around 20 cm above the contour level and having a slope of 1:8 to 1·10 like a ramp, both on the upstream and on the downstream side of the bund They should be pitched with grasses, wherever possible. Permanent weirs when constructed should be placed close to these ramp-cum-waste weirs

Designs

The minimum length of outlet required for a rectangular weir may be calculated by the following formula

$$Q = 1\,7\,L \times H^{3/2}$$

where

Q = Peak rate of runoff(cum) expected from the cumulative catchment

H = Flood depth over weir, taken normally 0.3-0 7 m

(Details regarding surplussing structures can be seen in Chapter 13).

Land levelling and grading

Land levelling or grading is the process of preparing or reshaping the land surface to a planned grade to provide a suitable surface Land levelling attempts to create a plane by cutting high areas and raising low spots The field so prepared, controls the water runoff, checks soil erosion and provides better surface drainage. Following factors decide the type and nature of levelling required in a particular holding:

1. Edaphic characteristics: depth of soil, infiltration and permeability characteristics.
2. Topography. prevailing land slope, designed land slope
3. Cropping pattern: commercial crop cultivation.
4. Method of irrigation.
5. Rainfall characteristics.

Prior to levelling design, the land development programme should be planned, including the location of field boundaries, irrigation, water supply system, drains and farm roads

12

Mechanical Erosion Control Measures for Non-Agricultural Land

We have discussed earlier about land capability classes V, VI, VII and VIII Extreme limitations of slope, erosion, shallow soils, moisture, climate, etc , make them generally unsuitable for cultivation About 26% of the forest land is prone to soil erosion Similarly, 17% of the total geographical area is classified as 'wasteland' They have negligible contribution to the Gross National Product (GDP) of Indian subcontinent. These unproductive lands are the source of maximum runoff, sediment deposition, siltation of reservoirs, formation of gullies and ravines, and droughts, floods, landslides, etc To prevent soil erosion on non-agricultural lands, mechanical and vegetative methods may be used. Mechanical measures are the basic and fundamental interventions which may be compared to foundation of a building and concurrent vegetative methods act as superstructure It is found that vegetative barriers developed on treated degraded slopes and lands are more sustainable and effective Measures like contour trenches may be ineffective within a year or two, while vegetative cover last for decades Both the measures go hand in hand

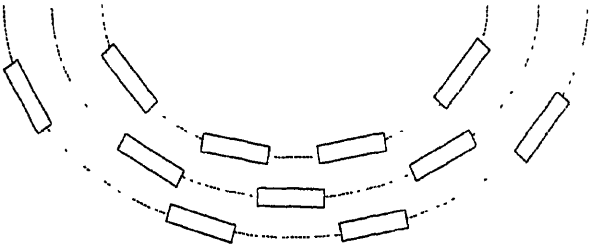
The wastelands, denuded and degraded forest lands and unused community lands have great potential for production and promotion of fuel, fodder, fibre, small timber, minor fruits, etc The mechanical erosion control measures may be adopted with supplementary afforestation techniques, grassland management, suitable horticultural practices, etc.

Eroded wastelands, also termed as badlands, depict situation where degradation has reached a final stage and they are irrevocably lost for any agricultural or forestry operations As they are very vulnerable, these badlands are the biggest source of runoff and erosion debris reaching the lower parts of the watershed Such lands should be primarily selected for intensive treatment in the uplands These lands are usually found on very steep slopes and have sparse or no vegetation Clearance of vegetation and faulty cultivation practices have resulted in rain splash, sheet, rill and gully erosions Such lands have been usually abandoned, leading to further deterioration The guiding and universal principle in erosion control on wastelands should be to make the most effective start at the lowest possible cost The natural processes should be allowed to take over the healing process of wounded degraded sloping badlands Mechanical and biological measures should be employed in unison and in integrated fashion. Large-scale and expensive engineering structures should be avoided as much as possible. Indigenous and appropriate prevalent techniques should be adopted for watershed treatment. The bare and eroded lands should be covered with protective vegetation This is most important objective for badland reclamation. This is, however, a very difficult task, as the sub-soil is poor, root-stock is absent, slopes are steep and the gullies are widened to dangerous limits. Extremely hardy crops may be introduced. In Jhabua, excellent results were achieved from *Prosopis juliflora* and *Jatropha* from seed sowing on badlands. Protective planting may have to be seriously considered. Grasses and legumes (*Proxy Biomass*) may play an important role in success of plantations and regeneration. In most cases, spot planting/seeding alone does not succeed and mechanical measures may have to be applied to encourage the seed germination and the establishment of planted shrubs Contour trenches, contour stonewalls, drainage line treatment help in moisture control and retention of topsoil which in turn has positive effect on the biomass growth Overlapping halfmoon-shaped small basins with a backslope is probably the most effective and cheapest method. The basins serve as mechanical silt traps and store runoff With the successful establishment of basic biomass, grasses, legumes, shrubs, etc., propagate themselves Protection using social fencing, biological and/or physical barriers may assist the regeneration from seeds or coppices Debris and water must be prevented from reaching the gullies Bunds, mechanical silt traps, small basins can be used over eroded areas Vegetative reinforcement around the perimeter of the basins are very helpful. Loose rocks and stones available at the spot may also be used for reinforcement.

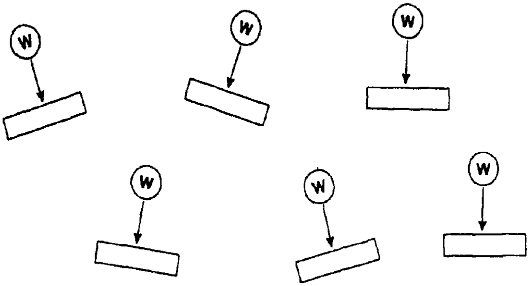
Contour trenching

Contour trenching is excavation of trenches along a uniform level across the slope of the land in upper reaches of watershed. Bunds may be formed in the transition and lower reaches from debris and material excavated from them Contour trenches decrease the length of slope into smaller sections which retard the rate of runoff and soil erosion Water collected in these trenches increase the moisture content and support the growth of vegetation. Contour trenches break the velocity of runoff and the water percolates through the soil slowly and travels down. They also protect the contour or boundary bunds in agricultural land from the runoff from the upper portion of the catchment The trenches may be continuous or interrupted (staggered/intermittent) type (Figure 12 1). Continuous trenches store more water but their cost is very high. They require a very careful layout. Slight fault in using 'A' frame may result in ill-oriented trenches Staggered (intermittent) and continuous trenches should always be constructed on contours Contour trenches can be taken up on varying edaphic conditions and rainfall. Generally, trenches get filled with soil over a period of time So, promotion of grass beds in intermittent spaces among the trenches and plantation of soil binder trees/shrubs on the upper edges of the trenches is beneficial Alternatively, 30 cm wall of small boulders/stones could be raised along the upper edge of trenches These boulders are easily available from the excavated earth or are freely available on the surface grassbeds of *Stylosanthes hamata, Panicum peniselatum* (dinanath) Trees/shrubs like *Anona squamosa* (sitafal), *Jatropha curcans* (ratanjot), *Prosopis juliflora* (vilayati babool), *agave*, etc., may be successfully taken up on the upper edges of the trenches through seed sowing Similarly, plantation through seed sowing inside the trenches increase the longevity of trenches (see Plates 29 a, b and 30 a, b)

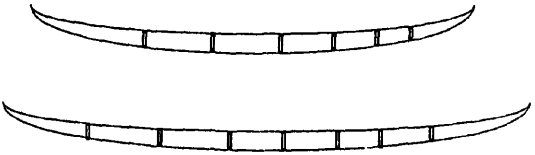
Figure 12.1 *Contour trenching*



(A) Staggered contour trenches



(B) Orientation of contour trenches in highly undulating land to capture maximum water, W shows direction of slope or flow of water



(C) Continuous contour trenches

Plate 29 (a, b) *Staggered and continuous contour trenches are effective means for SWC on hilly terrain Proper contours should be maintained while digging these trenches*

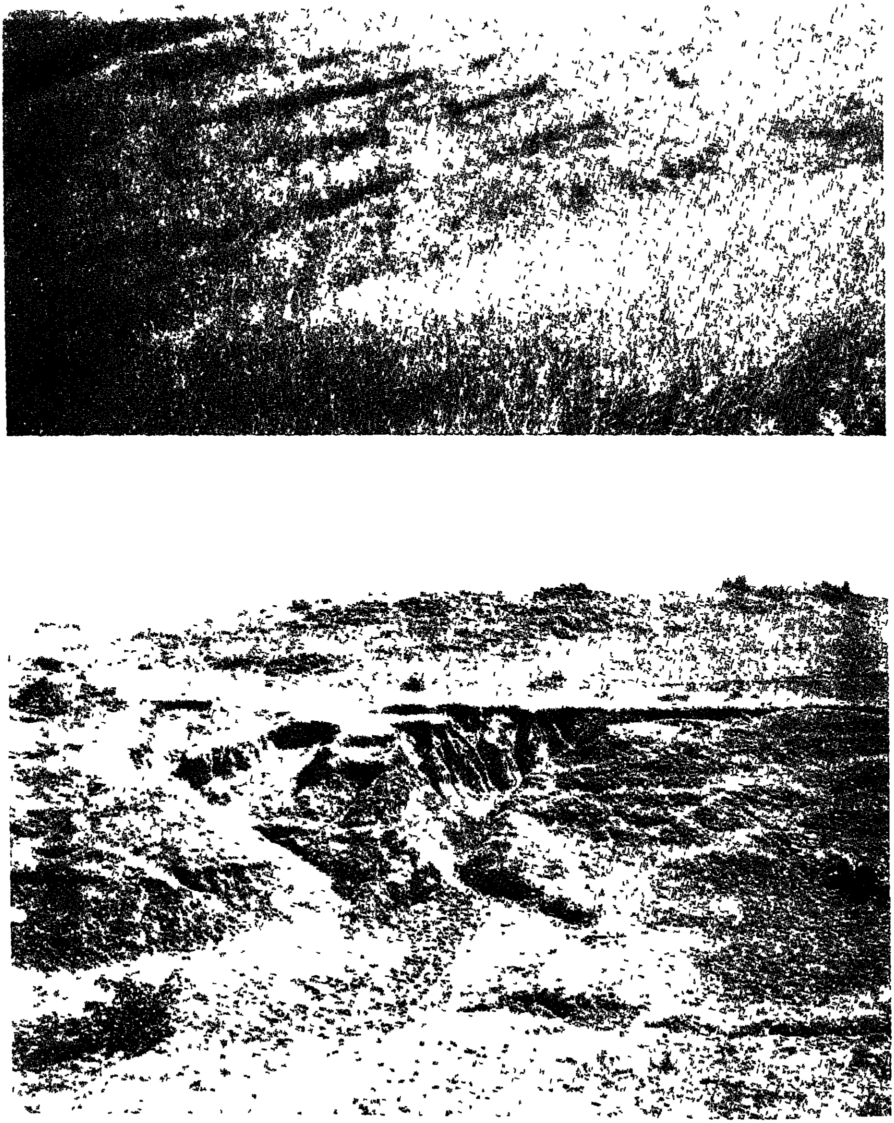


Plate 30 (a, b) *Contour trenches should be reinforced with vegatative barriers Hardy species like Jatropha (ratanjot), Prosopis juliflora (vilayati babool), Anona squamosa (sitaphal), etc, can be taken on bunds along the trenches*

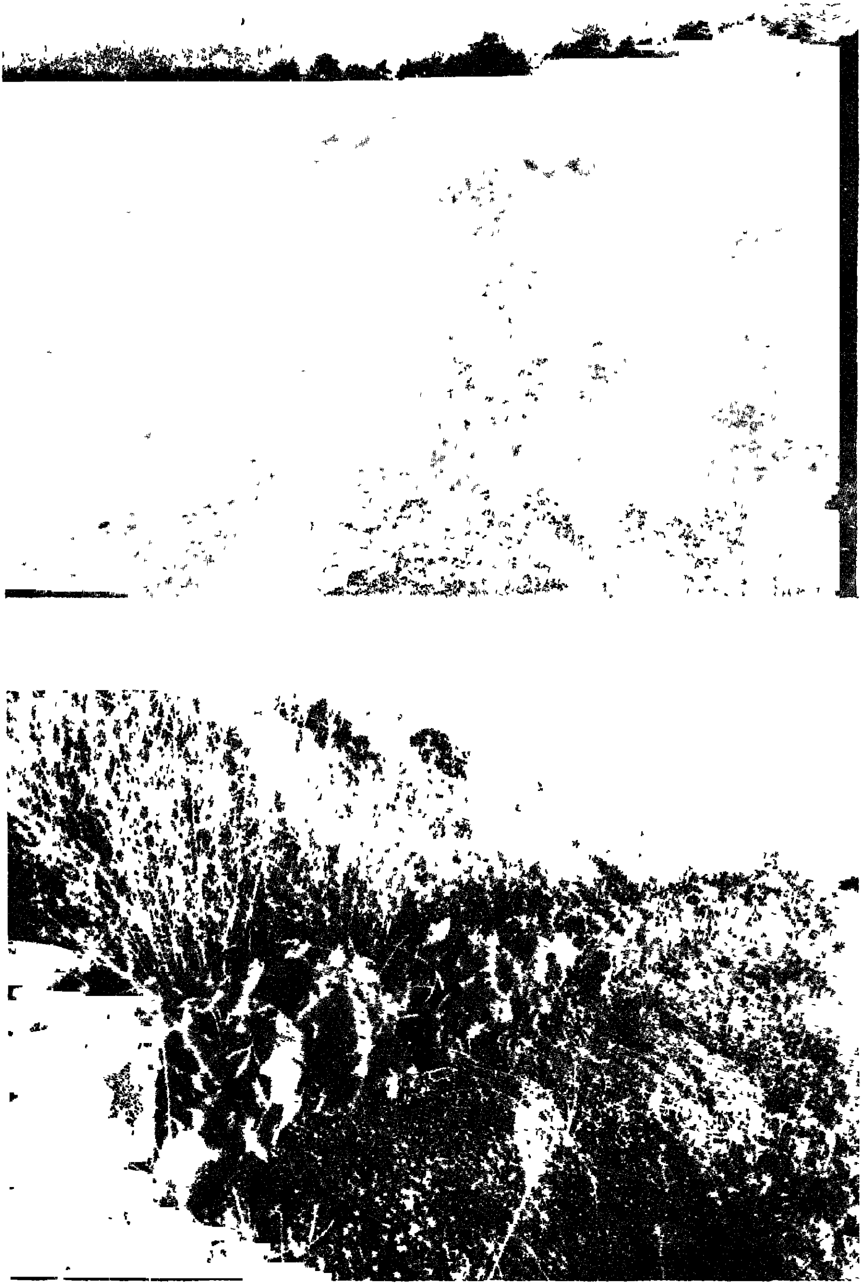
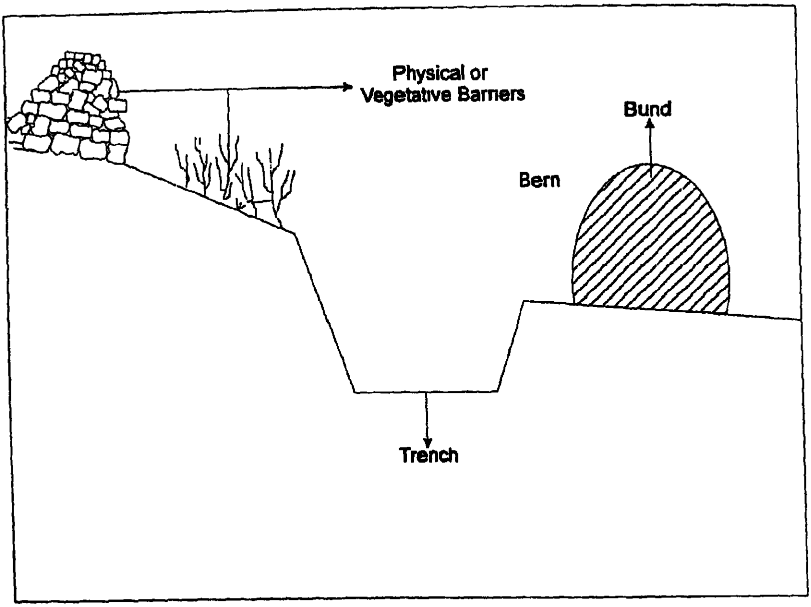


Figure 12.2 *Cross-section of contour trench*



Generally, the height (depth) and width of a trench depends upon the soil depth. Usually, the cross-section area of a contour trench is 1000 sq cm to 2500 sq cm. The trenches which are commonly used are 30x30 cm or 45x45 cm. The depth of the trench can be reduced when the soil depth is low and the underlying strata is hard. In such a case the width may be increased (Figure 12.2). The trenches can have 'U' or 'V' shapes. The length may vary from 2 m, 3 m, 5 m, 7 m (for intermittent/staggered trenches) to 100 m, 200 m, 300 m (for continuous trenches). The volume (length × height × width) of the trenches in an area depends on annual rainfall in general and peak rainfall in 24 hours in particular. For example, the volume of trenches in 1 ha land with 50 mm peak rainfall (in 24 hours) is:

$$0.05\text{m} \times 10{,}000\text{m}^2 = 500\text{m}^3$$

If the size of trenches is 30x30 cm, then the total length of the trenches required should be:

$$\frac{500}{0.3 \times 0.3} = \frac{500}{0.09} = 5556\text{ m}$$

The above method can at best be used as a thumb rule. In low rainfall areas, continuous trenches are preferred. Various methods and techniques used in laying out contours are given in Chapter 6.

Horizontal intervals between contour trenches depend upon the rainfall, slope and soil depth. When the rainfall is high, slope is high or soil depth is low, then the distance between two trenches should be less. Generally, high gradient terrain may have horizontal distance of 8-9 m between contour trenches, while less sloping terrains may have 20-22 m horizontal interval. Cross ties should be there in every 10-15 m intervals of a continuous trenches to check the runoff However, the height of cross ties should be less than the depth of the trench. Shouldering of these trenches increase the water conservation capacity.

Vertical Interval (VI) $= \frac{30\,S}{2} + 60$ (for low rainfall areas)

$= \frac{30\,S}{2} + 60$ (for high rainfall areas)

where, S= land slope (in %)

Horizontal interval between two trenches (HS) $= \frac{VI \times 100}{S}$

where
VI = Vertical interval (m)
S = Land slope (%)

In short, the number and density of trenches is high in areas with high land slope gradient, high rainfall intensity and/or low soil depth Likewise, the number and density of trenches is low in areas with low land slope gradient, low rainfall intensity and/or rich soil depth

Gully control measures

Gully formation takes place due to improper and injudicious use of the land, usually on steep slopes Thin layers of soil from the unprotected sloping land is first removed by the flowing water Following sheet erosion and continuous neglect and misuse gradually leads to rill and then gully erosion It has been observed that the cost of reclaiming gullies on sloping agricultural land is so high that the reclamation can hardly be justified in simple economic terms The cost of reclamation is mostly higher than the cost of the land itself. Thus, prevention of gully erosion is cheaper in financial terms as compared to control after their formation Even then, watershed programmes in India focus on gully control measures in soil and water conservation treatment plan. This is due to the fact that there is acute shortage of land in the villages and the potential danger the gully may create on upstream and downstream lands It should be remembered that gully control methods should be judiciously tried due to there high capital and labour intensive nature The investment should not be more than the benefits accrued The benefits may include cost of land reclaimed, cost of assets and structures that are protected from the ill-impacts of advancements of the gully, extent of prevention of sediment flow into reservoirs and channels, effects of moisture control etc A serious cost-benefit analysis may be useful in determination of gully control measures and their extent For early and initial gullies due to their higher damage potential, higher investment for control measures is justified. For naturally healing gullies that have a limited potential for further damage may not justify high investments. Practically, it has been observed that the project implementing agencies dwell in intensive gully control treatment measures, which can be easily avoided It is also desirable to include gully control sub-plan in the action plan. This would ensure control of runoff from the watershed area and retaining the runoff in the drainage area itself

It is advisable to try other methods, before concentrating on gully control measures, to retain the maximum possible runoff in the watershed This may reduce or even eliminate the need for treatment of gullies. Measures such as contour farming, bunding, terracing, retaining walls, trenching, strip cropping, sub-surface and mulch tillage, ridge planting, etc., may be easily and beneficially tried and they can significantly help to keep part or whole runoff in the field. This would substantially reduce the amount of flow in the gullies and automatically reduces the cost of control Another effective method of reducing the cost of gully control is to divert the runoff away from the gully. The excess runoff should be conveyed safely to a suitable outlet Graded terraces and field diversions can be used to discharge excess water safely into grassed waterways. It is important to ensure that outlets of such diversions do not form gullies.

In circumstances where gully is located in a natural depression and the rainfall and soil conditions cannot retain entire runoff in the watershed, the runoff may have to be conveyed through the gully. This method should usually be adopted as the last resort. Mechanical structures and vegetative barriers should be built at required locations and intervals to facilitate safe disposal of the runoff through the gully

Stabilisation of gullies through vegetative barriers is a difficult task, especially when the gullies have to be used to convey runoff during the time plantations are started. In these cases, mechanical methods may have to be adopted to prevent washing away of plantations in the gullies by the large volume of runoff Such protective methods will be temporary. Vegetative cover and barriers when established will be able to take care of the gully. When mechanical measures for gully control are essential, then permanent structures such as masonry check dams, flumes, earth dams supplemented by vegetation, should be provided over critical portions of the gully (see Plate 32).

The main objective of gully control measures is to reduce the amount of water runoff through gullies. Gully heads in particular should be completely protected by interception ditches which spread the water over the treated area. Diversion ditches all along the gully walls at small intervals and in a herring-bone pattern should further divert water from the gully sideslopes, away from the gully walls and spread it over the same protected area This may be simple in V-shaped gullies, but start closest to upper edge of the vertical walls Gully plugs and silt traps using locally available material, should be used on the gully floors. Specific plantations may act as live silt traps and may be protective to the mechanical measures.

Exhaustive and monolithic engineering structures should be avoided under all circumstances. It has been observed that such costly mechanical structures collapse or become useless after a very short time The only way to control gully erosion is from the top, above the gully head and along its walls on both sides. Nature will take care of the rest, with initial assistance to start the process, which may take many years to complete In low gradient agricultural and productive areas with single or shallow gullies and good soil cover, reclamation of the land may be considered. If the gully is not too deep and is located

Plate 31 *Boulder checkdams are effective in gully control on undulating terrain When iron-mesh support is provided to them, especially in gullies with high runoff, they are called gabionic structures*

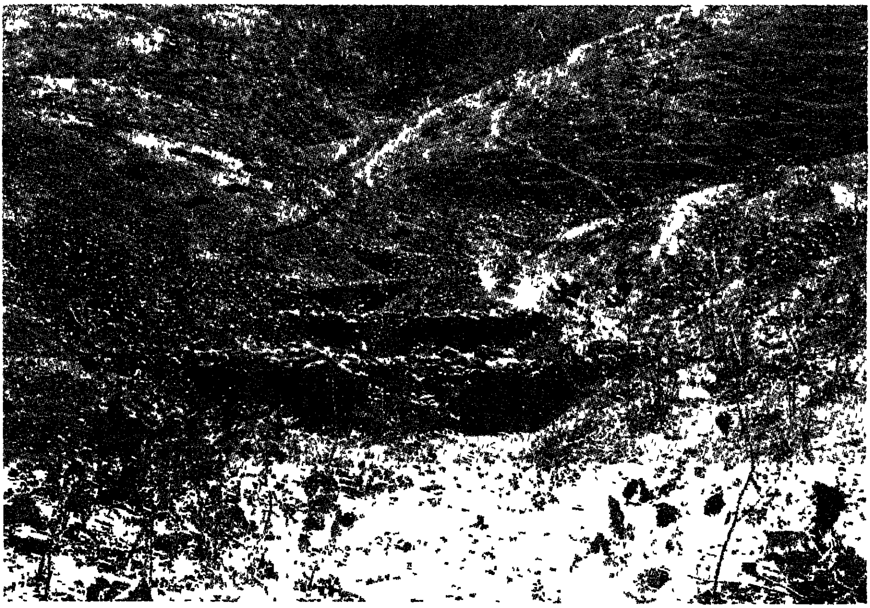


Plate 32 *Vegetative barriers on wastelands are more cost-effective than physical barriers Agave is recommended in arid and semi-arid areas*

in the cultivable areas or areas where it interferes with cultivation, mechanical filling by natural labour or machinery may be justified. Due to its exorbitant cost such measures should only be adopted in exceptional circumstances Such reclaimed gullies should be carefully protected from running water by interception or diversion ditches. Filled in gullies may be gradually transformed into grassed waterways by network of interception ditches and protective plant cover.

Vegetative control methods

Vegetative control measures are cheap, long-lasting and sustainable for gully control. The vegetation may be either grasses, shrubs or trees. The vegetation also generates additional income from such watersheds. The vegetation, in the initial stages, should be protected from runoff and grazing, at least till the time it is established. Direct seed sowing, sodding or planting techniques may be used for gully reclamation.

(a) *Sod flumes*: For a small drainage area, the gully can be used as a flume The gullied areas should be covered with sods to provide the requisite protection from conveyed water flow through them. The overfall and the sides should be cut to proper slope of 6:1 or flatter, before sod planting is taken up. The flume should be wide enough to have less than 30 cm depth of flow. This would ensure non-erosive velocity. Strip sodding may be used effectively in low runoff areas Costlier options like solid sodding may have to be taken up in medium runoff areas, in which a complete coverage due to planting of larger size is provided

(b) *Sod checks*. Two types of sod checks, viz , sod strips and sodded earth fills are commonly used for gully stabilisation The sod strips are sods placed in strips along the gully at a regular interval A minimum of 0.30 m width should be provided and extended sufficiently above the expected water level. For stabilising small and medium size gullies with small drainage area, sodded earth fill (earth fill along with sodding) can be used The earth fills are located at suitable intervals, generally at critical points along the gully The height and spacing should be so adjusted that the top of a fill is at the same level as that of the base of the next fill upstream. Side slopes of 4 1 or more should be used for the stability of the structure The centre of the structure,which acts as a spillway, should be lower than the sides Both the sides of the structure should curve towards the upstream Solid sodding should be used on the top and the downstream side. It should continue to the sides to a height of 15-30 cm above the maximum expected water level

(c) *Shrub checks*. In small gullies, with mild slope and limited drainage area, shrubs and tree branches can be used for stabilisation. Trenches are dug across the gully slope and shrubs are placed in them and covered with soil. Stocks or wooden poles can be used to hold them in position They retard the flow of water and thereby reduce the velocity of flow and trap the moving soil Gradually, the vegetation growth would stabilise the gully

(d) *Trees and shrubs* Various species of shrubs and trees may be planted for gully control The ground is well prepared and suitable species are planted upto optimum moisture conditions Biodiversity should be maintained by using multiple suitable species Proper maintenance and protection (specially from grazing) are essential.

Temporary gully control structures

Temporary gully control structures in watershed management programmes for non-agricultural lands are useful for gully control, sediment storage, surface water disposal, water level control and groundwater recharge. They may be constructed by using the readily available local material like earth, sod, rocks or boulders, wood, brush, etc. They are helpful in supporting, protecting and enriching vegetative cover. Such temporary structures are recommended for gullies with small drainage areas. It is very essential to grow vegetative cover and barriers along with the construction of these structures. A series of temporary checkdams are more helpful and useful than a single large concrete checkdam. They should be constructed from top towards bottom. These dams should be so placed that the crest level of one coincides with the base level of the next dam upstream. Generally, a grade of 0.1-0 5% may be provided.

Checkdams

A series of checkdams reduce the velocity of runoff leading to sediment storage, moisture control and recharge. Construction of series of checkdams from top to bottom transform the longitudinal gradient into a series of steps with low risers (see Figure 12.3). In Jhabua, a series of earthen or boulder checks have shown effectiveness and sustainability over a span of years in gully control Completion of checkdams on first line of drainage has been ensured before moving to the second, and third line of drainage Earthen checkdams have proved to be the cheapest. They have been strengthened by vegetative cover especially of grasses, *jatropha* and *agave*. These checkdams are also made of loose rocks, boulders, brush, wire, etc. Regular checks of masonry or concrete structures may be essential to provide permanence The temporary checkdam series perform following basic functions (a) collect sufficient soil and water to enable the proper growth of vegetative cover, and (b) check channel erosion until sufficient stabilizing vegetation can be ensured. The vertical interval between two checkdams should be equal to the height of a checkdam (Figure 12 4) In Jhabua, earthen checkdams have been found effective in gullies with less than 1 8 m depth and 4 m width. These checkdams need continuous repair and maintenance an-

Figure 12.3 *Checkdam*

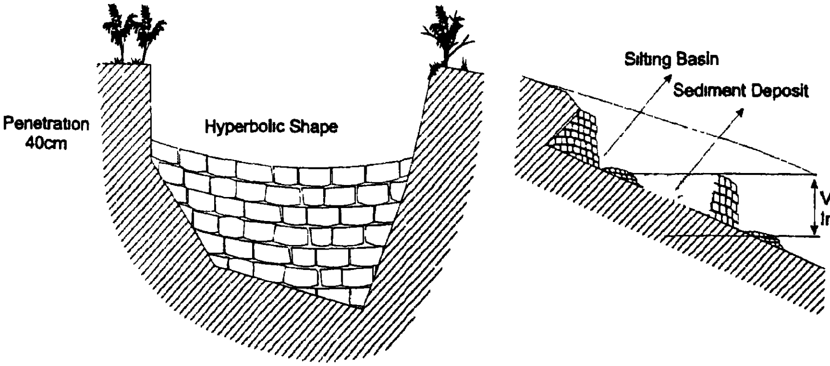
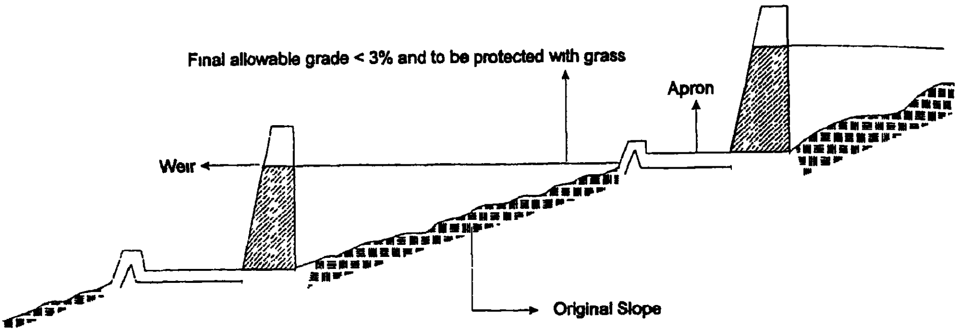


Figure 12.4 *Example of checkdams. Gradient between head of lower weir and toe of next upper weir not to exceed 3%*



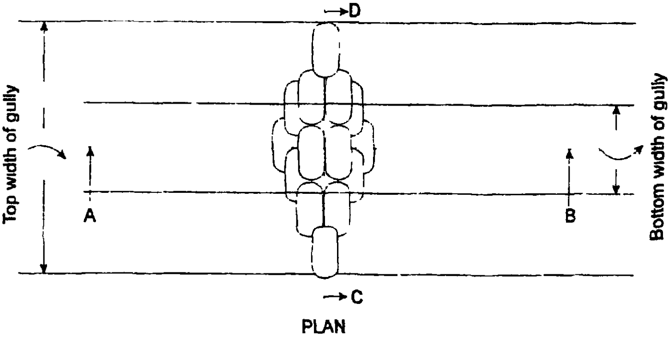
nually. They should also be inspected and repaired after heavy downpour (also see Figure 12.5)

Brushdams

Brushwood checkdams are recommended in areas where wooden posts are in abundance These structures are least permanent of all types, but they are cheap and easy to construct They can be economically constructed in small gullies of 1.2-1 5 m depth. They have not been utilised or constructed in Jhabua due to their susceptibility to pest attack, non-availability of wood in degraded areas and high costs involved in repair and maintenance. Similarly, it is advisable to discourage the brushwood dams in watershed projects in other districts. The brushwood dams may however be taken up in small gullies in dense forested areas They are essentially of two types·

(a) *Single row post brushdams* This essentially is a single row of wood stacks, to which long branches of trees laid lengthwise to the gully are tied with their butt end upstream The longest branches are laid first and progressively shorter branches are stacked on the top For the construction, the sides of the gully are cut to a slope of 1.1 and a trench of about 15 cm depth is made into the bank of the gully. The 15 cm excavation is carried up into the bank as high as required The wooden stacks of around 7 5 cm diameter are driven into the soil to a minimum depth of 90 cm into the bed The centre is made lower than the sides to form a notch to enable the side discharge maximum runoff A layer of straw is placed at the bottom and long branches are laid, lengthwise to the gully over it. After pressing them another layer of straw is placed over which shorter branches are laid. This process is repeated till a dam of the required height at the gully bed is achieved The brush is anchored onto the stacks by means of galvanised iron wire Intermediate stacks are driven in and the brush anchored onto them to prevent it from being thrown away from the

Figure 12.5 *Synthetic fibre bags filled with sand for checkdams*



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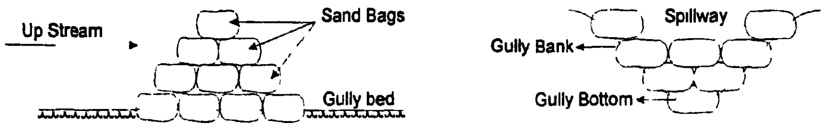


Section - AB

Section - CD

bed by flowing water Over a period of time, the green leaves rot, loosening the branches and the dam becomes vulnerable Additional rows of stacks can be used Heavy boulders may be placed over them to keep them in position After completion, care should be taken to see that the centre is kept lower, so that it can act as a spillway

(b) *Double row post brush dam* This method is used in the control of medium-sized gullies (2 m deep and 5 m wide) and have a contributory watershed of 40 ha or more The straw and brushwood are laid across the gully between two rows of woodposts. The distance between the rows is normally not more than 0 9 m The stacks are driven 0 9 m apart to go at least 0 9-1 2 m into the hardbed of the gully. Brushwood apron is held together by galvanised iron wire Double row post is more stable than single row post.

Semi-permanent gully control structures

Those structures have a longer survival and require low cost maintenance These structures may not require the support of protective vegetative growth cover for controlling the gully They are recommended where requisite material is available in abundance Such structures are effective in steep gullies traversing hilly terrain

Loose rock/boulder dams

If loose rocks or boulders of good size are freely available then they can be used for constructing loose rock dams The construction site is cleared and side slope of 1·1 or flatter than that are ensured The bed of the gully is excavated to a depth of about 0 3 m and stones are packed into it The packing also extends to the top of the sides. The stone filling should go upto 0 3-0 6 m into the stable portion of the gully side to prevent end cutting. The thickness of the apron packing should not be less than 0 5 m and the gully sides above the apron should be protected with stone pitching The middle portion is kept lower so that it functions as a spillway. Bigger-sized stones should be placed on top to prevent the pitching being dislodged by water current Flat rocks of larger size may be spread on the downstream side of the spillway as apron Flat stones if available are best as they provide more stability Irregular-shaped rocks or boulders also may be used by encasing them with woven wire netting (woven-wire dam) The woven wire casing does not allow the rocks to be carried away by flood water. Though, in India, stability is secured by using largest size stones and carefully packing, bedding and compacting them The boulder check dams have been successfully used in medium-sized gullies on 30 degree or more gradient terrains The boulder dams have been secured even in heaviest of rainfall, surviving numerous monsoons. They may be supplemented with vegetative cover and barrier.

Plank or slab dams

This method is not recommended due to heavy cost of timber involved in the construction However, in north-eastern states of India, where timber is available easily, these dams may be constructed for gully control They are more useful for control of large drainage area gullies compared to other measures. Wooden poles of suitable sizes are driven in the gully bed across its length to a depth of about 1 m and at about 1-1 5 m apart Wooden planks cut to proper shape and size are tightly fixed with the poles If the bottom plank cannot fit tightly with the ground, then the bottom may be sealed in a different manner At the centre of the dam, a spillway of suitable capacity should be provided The upstream face of the plank should be filled with soil and should be compacted well The fill should have a stable side slope which depends on the nature of soil. On the downstream side of the spillway, rocks, sod, etc , should be placed to act as a apron

Log and pole dams

Log and pole dams may also be constructed in areas where the cheap timber is available in plenty. Plank dam requires some processing of the timber It is, therefore, more costly than a logdam In a plank dam it is possible to achieve tight fit between the planks, which results in water-tight construction Such effective construction is not possible with logs The method of construction of log and pole dam is very similar to that of plank or slab dam (Figure 12 6)

Gabionic checkdams

If stones are readily available and their irregular shape makes them unsuitable for loose stone checkdams Depending on loose stone availability for construction, the gabionic checkdams are very helpful If the expected water velocity is very high, gabion are recommended in place of loose rock dams A *gabion* is a rectangular shaped cage made of galvanised wire, which is filled with locally available boulders, rocks or stones The gabion may be conveyed flat and are folded to shape at the construction site In Jhabua, a simple one day training has resulted in construction facilities at the doorstep from simple medium-gauged galvanised iron wire mesh Usually, gabions are 1m wide and 0 75-1 m high with varying lengths ranging between 2-10 m (Figure 12 7) The gabionic check dams are constructed by connecting several gabions in horizontal and vertical direction The gabionic checkdams are very stable and semi-permanent in nature These structures are flexible, they may even change shape automatically according to the streambed, even when the bed shape changes due to erosion, without losing stability Soon after the gabionic dam con-

Figure 12.6 *Log wood pole checkdams*

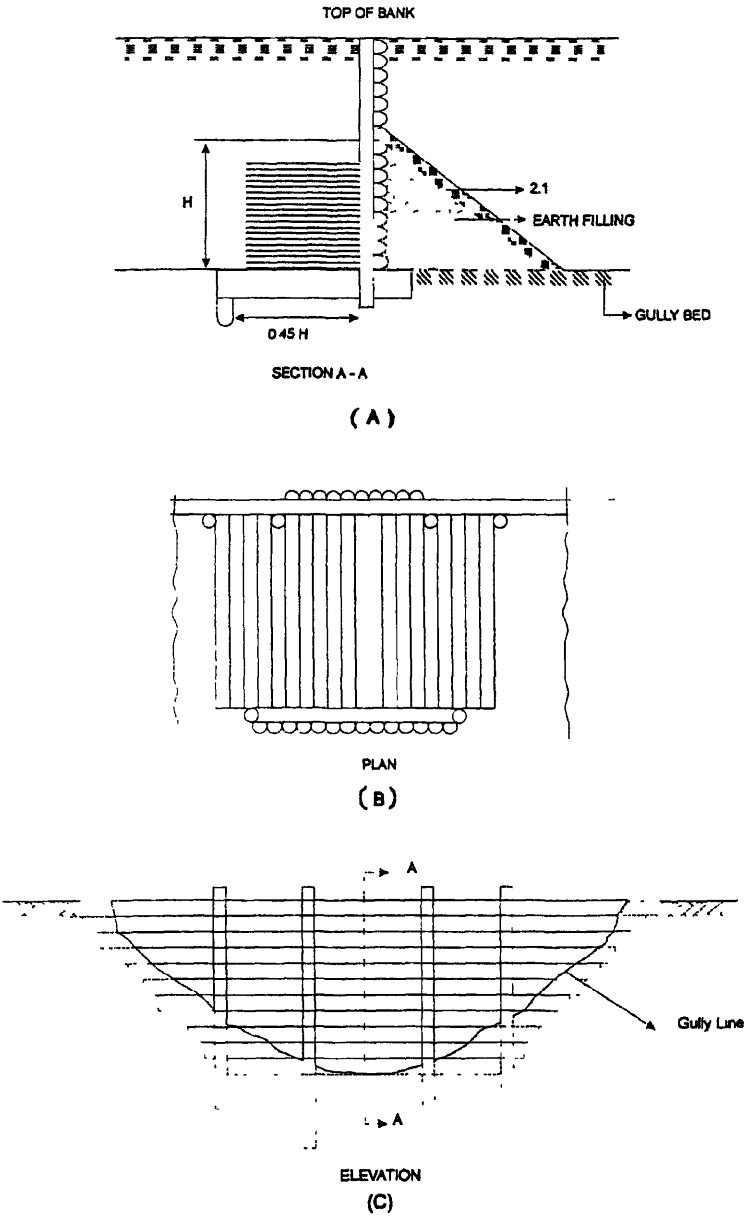
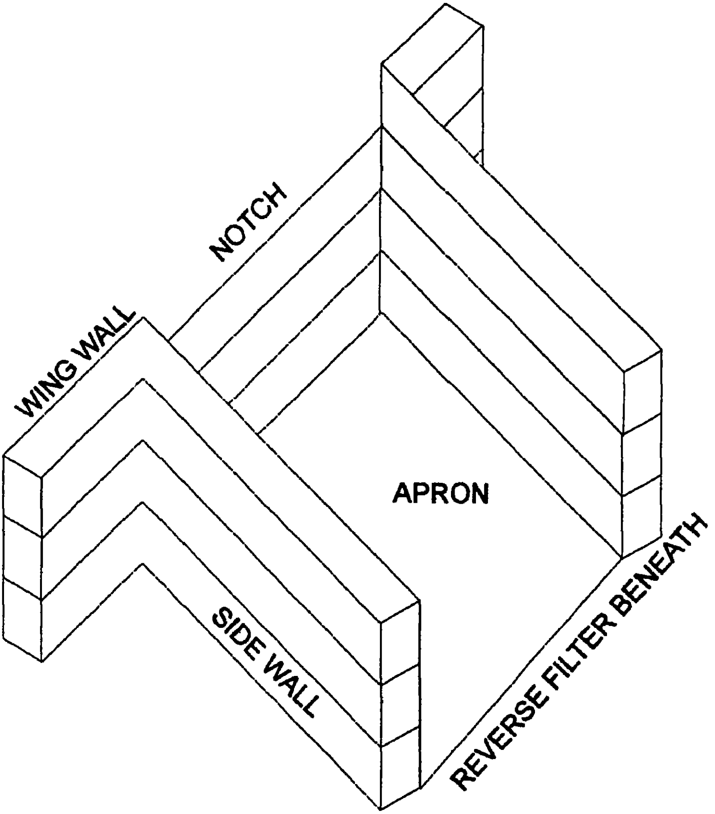


Figure 12.7 *Basic gabion structure (perspective)*



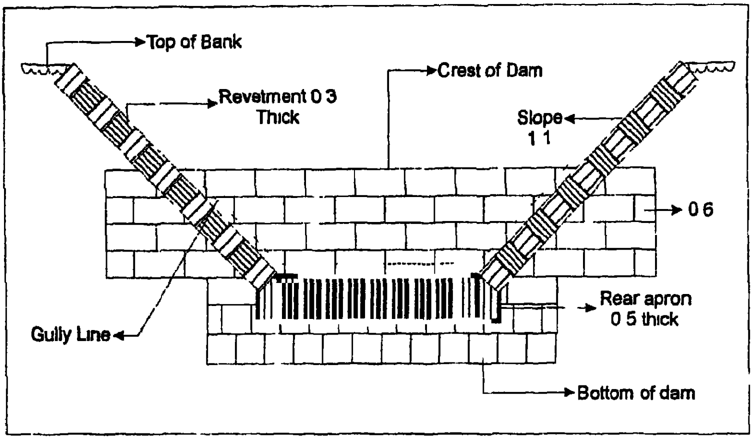
struction, it remains permeable for a season or so. It retards water velocity and accelerates sediment retention Complete filling behind gabionic checkdams has been achieved by soil deposition within two seasons in Jhabua district Thus, reclamation of land is possible (see Plates 31 and 33 a, b).

Permanent control structures

In large drainage areas, badly eroded gullies, unsuitable conditions for establishment of vegetation, high intensity of rainfall and very steep catchment, vegetative control, temporary or semi-permanent gully control structures are unable to control the advancement of gully or stabilise it Material for temporary or semi-permanent structures may not be available locally or at a low cost High degree of safety, stability and permanence may be essential to control the advancement of gully in various circumstances. In such cases, permanent structures of masonry and concrete play an important role in reinforcing or supplementing other measures. Permanent structure fulfill the following objectives (Figure 12 8)

Plate 33 (a, b) *Boulder walls break the velocity of the runoff and with a period of time, when soil is trapped in them, they help in water conservation as well Vegetative reinforcement provides stability and logitivity*

Figure 12.8 (a) *A dry stone dam (permanent control structure)*



Selection Elevation looking up gully

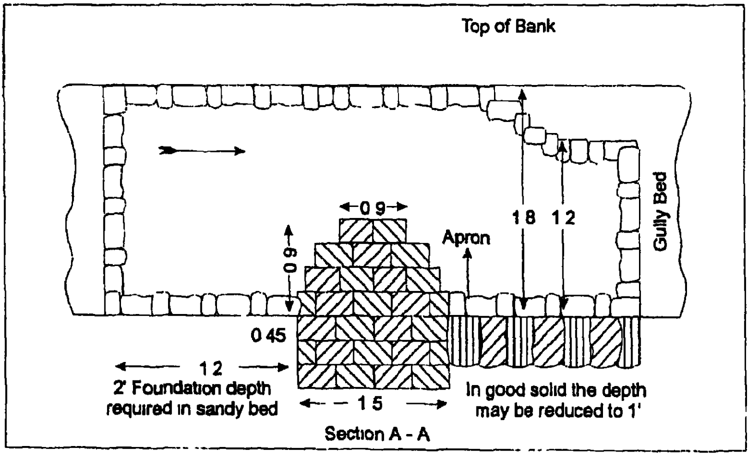
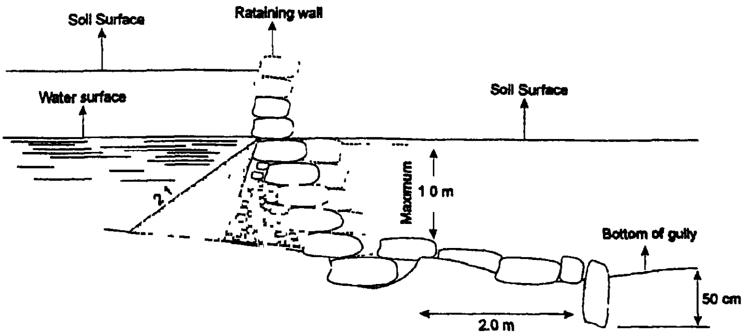

Top of Bank
Gully Bed
0 9
0 9
Apron
1 8
1 2
0 45
1 2
2' Foundation depth required in sandy bed
1 5
In good solid the depth may be reduced to 1'
Section A - A

Figure 12.8 (b) *A dry stone dam (permanent control structure)*



1. it reduces the water runoff from gullies,
2. it checks or stabilises the advancement of gullies,
3. it helps in soil retention and sedimentation,
4. it controls moisture and helps in recharging sub-surface water bodies, and
5. it collects water into water bodies.

Essentially, these structures convert the kinetic energy of discharge within the structure in a manner that both the structure and downhill channels are protected from damage. There are three types of spillways in permanent structures: (i) drop spillways, (ii) drop-inlet spillways, and (iii) chute spillways. Permanent structures are designed and constructed for a long duration of 20-25 years. Therefore, runoff expected from the heaviest rainfall that may occur once in 20-25 years should be considered for design. It is essential to select proper structure for a given location and function for successful and economical control of erosion or runoff. Each type of structure has its own range of use for a given set of existing conditions. Generally, there is one type for a given condition which will provide the most economical control for proper selection of site. Field survey should be conducted and foundation data of all practical alternative sites should be obtained. The foundation investigations may require one or two test holes for determining various types of soils. The foundation material should have the required supporting strength and resistance to sliding It should be reasonably homogeneous to prevent differential or uneven settlement of the structure

Gullies on very high gradient terrain, steep portion of channel and large width of the gully necessitates construction of permanent structures The degree of control or protection and the size of the watershed along with foundation conditions are primary considerations in structure selection.

Most of the commonly used structures consist of four major components.

(a) *Embankment*: It checks and diverts the flow of water and directs it through the spillway The embankment usually extends from the spillway to higher ground or to a vegetative spillway In farm pond, the embankment impounds water and discharges storm flow through the spillway

(b) *Spillway inlet*: Water enters the spillway through the inlet. These may be in the form of a box, a weir or a culvert type entrance Vertical walls extending into the soil foundations under the inlet (cutoff walls) prevent water seepage under the structure. To prevent seepage and erosion around the ends of the structure, vertical walls extending laterally from the inlet (headwall extensions) are constructed.

(c) *Spillway conduit* The conduit receives the water from the inlet and conducts it through the structure The conduit may be closed (box or pipe) or open (rectangular channel). Cut off walls and anti-seep collars are also constructed.

(d) *Spillway outlet* The water leaves the structure through the outlet It discharges the water into the channel at a safe velocity The outlet may be cantilever type, a plain apron outlet, or an apron with any type of mechanism minimising the erosive effect of water

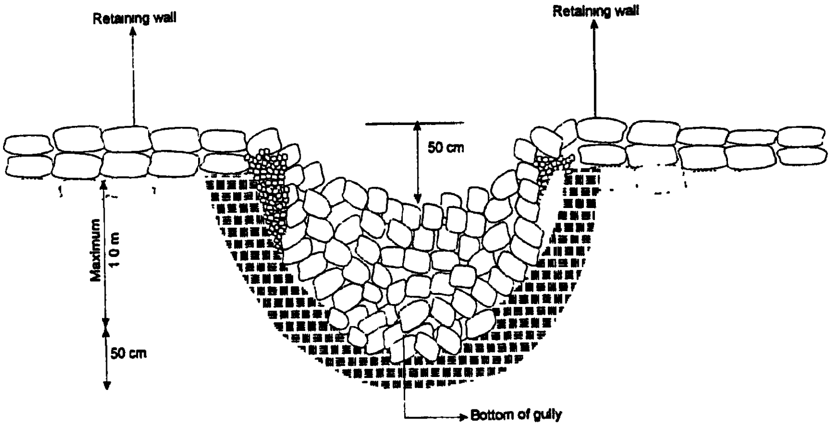
The outlet of a spillway should be so designed that its function or stability can not be reduced When sediment deposition is a problem, then the outlet of the spillway should be designed in such a fashion that deposition will not interfere with the spillway discharge during the life of the structure. The design of the structure should be such that after flowing through the structure, the water does not cause damage to the downstream structures Dimensions of the various components of the structure from stability analysis should be done considering the various forces acting on the structure. They are (a) water pressure on the structure, (b) seepage pressure underneath the structure, and (c) pressure due to overflow over the structure

Drop spillways

The drop spillway is a weir structure in which the flow passes through the weir opening to an apron or basin located below the weir. The flow passes to a downstream channel at a non-erosive velocity When the drop is limited to about 3 m, drop spillway is a suitable gully control structure Drop spillways may be constructed of reinforced concrete, plain concrete, rock masonry, concrete blocks with or without reinforcement or gabions, etc The drop spillway can act as a spillway for a reservoir if the total drop is not high When drop spillways are constructed along a steeply sloped channel at suitable location, the channel can be transformed into a series of gently sloping reaches (Figure 12 9). The drop spillway has following functional uses.

1 grade stabilisation in lower reaches of waterways and outlets,
2 grade control stabilising channels,
3 erosion control for protection of fields, roads, etc ,
4 outlets for surface water at the upper reaches and along drainage ditches,
5 reservoir spillways where the total drop is relatively low,
6 control of tail-water at the outlet of a spillway or conduit,
7 control of irrigation water, and
8 protection of the outlets, grassed waterways and sod chutes, etc

Figure 12.9 *Sketch of a drop structure*

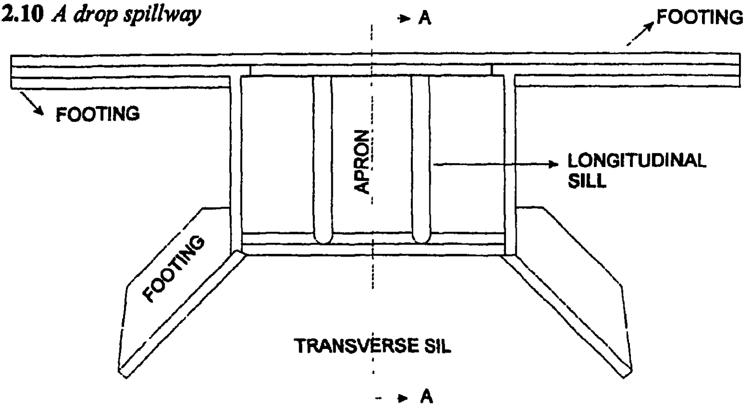


The drop spillway is an efficient structure for controlling relatively low heads, say upto 3 m However, when the head exceeds 3 m in height with a discharge capacity of less than 3m^3/s, the structure is costly If storage of water is needed behind the structure for irrigation and to reduce the peak runoff, drop spillway is not a suitable choice. A stable grade below the structure is very essential. Drop spillways have less likelihood of serious structural damage than for other types of structures. They are relatively simple to construct and cost less The rectangular weir is less likely to be clogged by debris than the openings of other structures (Figure 12 10).

The site should be so selected that the spillway can be located on a reasonably straight section of channel, with no upstream or downstream curves within at least 30 m of the structure. It is often desirable to straighten the channel alignment upstream and downstream of the spillway, so that it merges smoothly with the existing channel. Poor alignment may result in a reduction in discharge capacity and excessive scouring of the embankment and channel banks The site selected should provide an adequate foundation for the spillway

For masonry and gabionic structures, the thickness of the apron may be increased by 1 5 and 2 times respectively. Top widths and minimum base width of headwall, sidewall, wingwall and headwall extension for different wall heights for masonry construction are given in Table 12.1

Figure 12.10 *A drop spillway*



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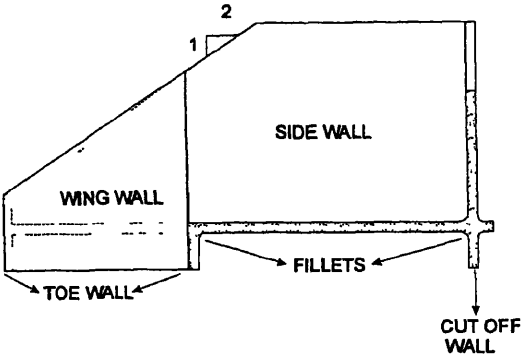
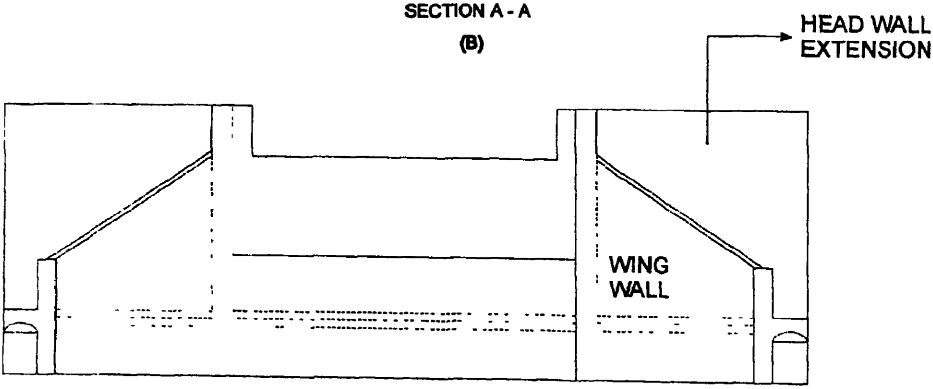
(A)



SECTION A - A

(B)



DOWNSTREAM ELEVATION

(C)

Table 12.1 *Drop spillways in stone or brick masonry*

Description	*Headwall (m)*	*Sidewall (m)*	*Wingwall and headwall extension (m)*
Minimum top width	0 45	0 30	0 30
Height (h)	*Recommended base widths (m)*		
0 5	0 45	0 30	0 30
1 0	0 67	0 55	0 40
1 5	1 00	0 82	0 60
2 0	1 33	1 10	0 80
2 5	1 67	1 37	1 00
3 0	2 00	1 65	1 20
3 5	-	-	1 40
4 0	-	-	1 60
4 5	-	-	1 80

Chute spillway

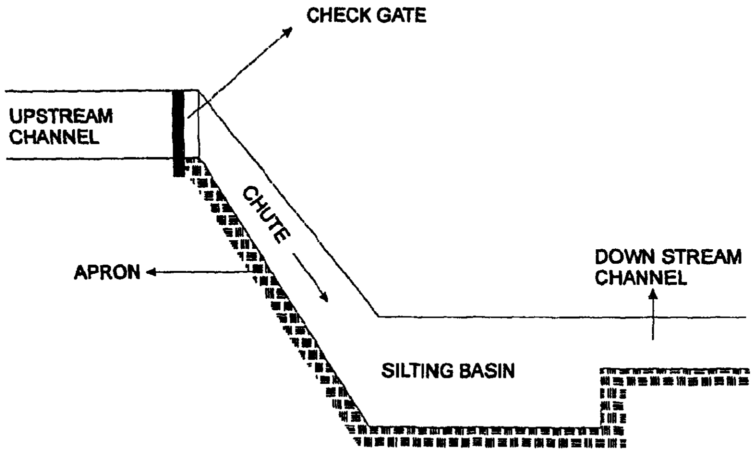
In case of overfall more than 4.0m, the drop spillway is not economical as it requires high cost of construction A chute spillway is an open channel with a steep slope, in which flow is carried at super-critical velocity rather than a free overfall as in a drop spillway. The flow enters through the inlet, flows through the vertical section and steep channel to the floor of the outlet. Maximum drop takes place through the channel. Reinforced concrete is the most widely used and safest material for large chutes. Plain concrete and masonary may also be used The chute spillway controls the gradient in either natural or constructed channels and serves as spillway for flood prevention, water conservation and sediment collection It is usually more economical than a drop inlet structure, when large capacities are required. Unlike a drop spillway or a drop-inlet spillway temporary storage of water cannot be provided above the structure. The structure may be considerably damaged by rodents. Seepage may weaken the structure, specially in poor drainage locations. The structure must be placed on compacted fill or on undisturbed soil in an abutment. Hydraulic designs and structural details may be gathered from any soil and water conservation handbook (Figure 12.11)

Drop inlet spillway

A drop-inlet spillway is a closed conduit generally designed to carry water under pressure from above an embankment to a lower elevation. An earthen embankment is required to direct the discharge through the spillway Vegetated or earth spillways around one or both ends of the embankment should always be used in conjunction with drop-inlet spillways Following are the functional uses of drop-inlet spillways.

1 grade stabilisation,
2 disposal system at lower end,
3 flood prevention,
4 surface water inlet for drainage or irrigation,

Figure 12.11 *Chute spillway*



5. principal spillway for farm ponds or reservoirs, and
6. principal spillway for debris basins.

The riser of a drop-inlet spillway may be of concrete, reinforced concrete blocks, masonary or pipe. The barrel may be of reinforced concrete, concrete or clay tile or corrugated or smooth metal pipe RCC pipes are also commonly used. It is a very efficient structure for controlling relatively high gully heads, usually above 3 m. The structures are well adopted to sites providing an appreciable amount of temporary storage above the inlet for high heads, the drop-inlet spillways require less material than a drop spillways The structure can only be located where satisfactory earth embankments can be constructed. Smaller size drop inlets are susceptible to blockage by debris. Pipe drop-inlets are confined to smaller jobs where

— the value of the improvement may not justify the use and cost of monolithic reinforced concrete,
— the project life is small, and
— large storage *vis-a-vis* size of watershed is available.

Structure designs and details can be gathered from soil and watershed conservation manual

Considering the National Guidelines, the treatment plan should not be too techno-cratic Hence, vegetative control, temporary and semi-permanent gully control structures are recommended. These can be planned, executed and maintained by SHGs, UGs and WDCs in particular and the community at large

Gully and ravine reclamation

It has been estimated in India that about 4 million ha of land are degraded by gully and ravine erosion. Another 5 to 6 million ha of land is being threatened by gully and ravine erosion. Gullies are universally distributed in all the agro-climatic zones. Degraded hillocks and mountainous terrains are infested with more extensive gully formation. The ravines are concentrated along with rivers of Chambal, Sabarmati, Mahi, Yamuna, etc., and the foothills of Shiwaliks and Himalayas It is also seen in the plateau area of eastern India.

Gullies are advanced stage of rill erosion as rill erosion is an advanced stage of sheet erosion They require costly structures and practices to control the further advancement of gully. The advancement of gully depends upon watershed characteristics and size, rainfall, soil characteristics, shape of the gully, slope of the channel and cultivation practices in the watershed. Following four different processes are involved in the development of the gully:

(i) Waterfall erosion at the gully head: Water falling at the gully head cuts the edge and caving of bank takes place. This detached mass of soil is carried away by runoff water. If the subsoil is loose, undermining proceeds at a faster rate More land area is covered by gully formation and gradually branches spread all over the area.

(ii) Channel erosion. It is caused by the water flowing through the gully or by raindrop splash on unprotected soil As much of the water passes through the gully head, lengthening of the gully takes place

(iii) In cold regions alternate freezing and melting of snow take place on the exposed soil banks and causes erosion

(iv) Due to undercutting, slides or mass movement of the soil takes place and huge quantity of soil is lost at a much faster rate.

Generally the following four stages are involved in the development of gully

Stage 1. Formation stage Channel erosion takes place by downward scour of the topsoil If the topsoil can provide resistance, this stage proceeds slowly

Stage 2 Development stage Upstream movement of the gully head and simultaneous enlargement of width and depth takes place.

Stage 3 Healing stage: Vegetation begins to grow in the channel and further erosion ceases

Stage 4 Stabilisation stage The gully bed and sides reach a stable slope and sufficient vegetation grows to anchor the soil and to trap soil flowing from upstream New topsoil develops and vegetative cover grows.

There are several systems of gully classification. According to one system, gullies are classified as per their cross-sections Depending upon soil, climatic conditions, age of the gully and type of erosion, it may be either V-shaped or U-shaped V-shaped gullies are formed due to scouring of soil by concentrated runoff in unprotected depressions If both the surface and sub-surface soil are easily erodible, then U-shaped gullies are formed Vertical walls are formed due to undermining and collapse of the banks Both type of gullies may be visible in the same channel

Another commonly used method of classification of gullies is based on drainage areas and gully sizes. Tejwani and Dhruvanarayana (1961) classified gullies into four classes According to this classification, very small gullies have depths and widths within 3 m and 18 m respectively Small gullies have depth within 3 m, bed width is greater than 18 m and side slopes may be between 8 and 15%. Medium gullies have depth between 3 and 9 m, bed width 18 m or more. Deep and narrow gullies generally have depths between 3 and 9 m and bed width less than 18 m.

It is important to extensively plan gully and ravine control mechanism. Large-scale map of the watershed area is essential for classification and detailed planning of works. Configuration of the topography, such as gully rims, gully beds, water courses and drainage lines, changes in the profiles of gully faces, and vertical faces of gullies are plotted on maps after a detailed topographical survey. It is also necessary to study the upper, middle and lower zone drainage patterns with respect to depth, width and side slopes of the gully.

Closure to grazing and other biotic interferences

Poor species of perennial and unpalatable grasses grow in eroded and degraded areas When gullied areas are closed to all kinds of biotic interference, soil and water losses progressively decrease and there is a marked quantitative and qualitative improvement in the yield of grasses. Tejwani et al (1961) and Singh et al (1971) reported that as a result of closure *Aristida funiculata, Themeda triandra, Heteropogon contortus, Dichanthium annulatum* species grow easily

Construction of contour graded and peripheral bunds

The purpose of these bunds is to retain as much precipitation as possible in semi-arid and sub-humid areas and safely dispose of the excess runoff in humid areas The advancement of gullies can be checked by retaining maximum water from the rainfall in the catchment itself by constructing contour bunds and terraces. Various studies at Valsad (Gujarat) have indicated that for protection of the table lands above the ravines, contour bunds of 0.9 m^2-1 2 m^2 cross-section spaced at 0.9-1.2 m vertical intervals are quite effective upto 6% slope. Alternatively, a shallow or elliptical channel with 6 m top width and 0 3 m depth has been found to be useful in cultivation and early filling up to the depression. For lands with 6-12% slope, bunds of 1.3 m^2 in cross-section at vertical intervals of 1.8-3.6 m are recommended. Grass ramps were provided in the bunds for easy flow of runoff water. Kamannavar et al (1977) and Nema et al (1980) found that contour and peripheral bunds of cross section of 0.9 m^2 with required pipe outlets and grass sodding of *Dichanthium annulatum* and *Cenchrus ciliaris* are the best suited Bunds need stabilisation through grasses or otherwise After four to five rainy seasons, cross-section of bunds become very less and they become useless owing to frequent breaching Studies at Valsad (Gujarat) have revealed that *Dicanthium annulatum, Amphilopsis glabra, Andropogon ischaemum* and *Cenchrus ciliaris* grasses provide excellent ground cover and good yield of fodder They have elaborate root system too *Panicum repens* and *P antidotale* provided poor root system but good ground cover while *Amphilopsis odorata* provided poor root system, but good ground cover and herbage (Srinivasan et al, 1962) At Agra, out of 11 grasses *Ciliaris spp* and *Pennisetum purpureum* were found to be excellent grasses for bund stabilisation

In case of less permeable black soils of the Chambal valley, where the rainfall is higher, graded bunds along with grass waterways and drop structures are better than contour bunds Peripheral bunds or diversion drains are provided above the gullies to divert excess water away from the gully heads so that gully head extension is stopped

Gully plugging

Gully plugs help in protection of gully beds by reducing speed of runoff water, redistributing it, increasing percolation, increasing siltation and improving moisture regime for establishment of vegetation.

Gully plugs of various materials, e.g., brush wood, live hedges, earth, sand bags, brick masonary and boulders have been tried. The size and material for the gully plug depends on the width, length and bed slope of the gully and anticipated runoff. At Valsad, gully plugs of various materials and located in various situations were constructed (Tejwani et al., 1960). In narrow gullies, whose width did not exceed 3 m live hedges, such as *Euphorbia spp.*, were planted across the gully beds in three rows spaced 9 cm apart and the stems at 9 cm; centres in each row alternatively staggered.

All types of gully plugs were effective either in retaining or retarding the runoff. Earth is the cheapest and the most readily available material and it is, therefore, easier and economical to construct the earthen gully plugs, whenever possible. Boulder gully plugs are equally effective if the material is available Brush wood is often available but there is likely to be shortage of wooden posts Moreover, brush wood gully plugs do not survive the severe white ant attack. In the long run they prove to be costly For the same considerations of short life and high cost, the sand bag gully plugs are not recommended. Brick masonary gully plugs are constructed at the confluence of all gully branches of a compound gully Specification for materials and location of gully plugs for rains are given below in Table 12 2

Table 12.2 *Specification for materials and location of gully plugs tried for ravines at Valsad*

Slope of gully bed (%)	*Width of gully bed(m)*	*Location*	*Type of gully plug*	*Vertical interval between two gully plugs(m)*
0-5	(a) Up to 4 5	Gully bed	Brush wood	Upto 3
	(b) 4 5 to 10 5	Gully bed and side branch	Earthen	Between 2 25 and 3
	(c) 7 5 to 15	At the confluence of 2 gullies	Sandbag	-
	(d) 7 5 to 15	At the confluence of all branches of a compound gully	Brick masonary	-
5-10	(a) Up to 4 5	Gully bed	Brush wood	Upto 3
	(b) 4 5 to 6	Gully bed and side branch	Earthen	Between 1 5 to 3

Reclamation of gullies

Small and medium-sized gullies can be conveniently and economically reclaimed for cultivation Deep and large gullies may not be economically viable for reclamation and should be kept under permanent vegetative cover of grasses and trees.

(a) *Reclamation of small gullies* It is simple to reclaim small gullies by clearing, minor levelling and construction of checkdams. Check bunds of 1 5 m^2 cross-section spaced at horizontal intervals of 30-40 m are effective Excess runoff at the end points of the bunds is disposed of by grassed waterways. Their positions are usually staggered in successive bunds. Temporary or semi-permanent gully control structures are constructed at the end of the gully.

(b) *Reclamation of medium gullies*: They are reclaimed by clearing, levelling and construction of a series of composite gully control structures at vertical intervals of 1.2 m. The tributary gullies from the main gullies are bench-terraced, though this is a costly venture. They are constructed especially when the gully sides have a uniform slope for a minimum length of 1 20 m. In Valsad, level terraces were constructed at 0.9-1.2 m vertical interval with inward gradient of 1 in 50 and longitudinal gradient of 1 in 200. The terracing requires stabilisation and careful maintenance for the first two years. The terrace faces, graded bunds and earthen or rocky check dams should be stabilised by growing suitable grasses like *Dichanthium annulatum* and *Cenchrus ciliaris*. Even in reclaimed medium gullies, cashcrop of orchards, agro-forestry, silvipasture or dryland horticulture can be economically grown even in rainfed conditions. Runoff water from the cultivable area may be harvested and stored in suitable storage or water harvesting structures

(c) *Reclamation of narrow and deep gullies*: Such ravines or gullies should ideally be left untouched for regeneration of grasses and trees. Social fencing, if properly implemented, may result in permanent vegetative cover over a period of few years. Suitable, fast growing and protective/productive species of grasses, trees, etc., should be raised on such gullies. In Mahi ravines, *Accacia nilotica, Albizia lebbek, Azadirachta indica, Dalbergia sissoo* and *Dendrocalamus strictus* have shown promising results Similarly, *Accacia nilotica* on the top and *Salix tetrasperma* in gully beds have been found suitable. Good grass cover should always be maintained.

Stabilisation of peripheral bunds

Bunds need stabilization through grasses or vegetative cover. If not protected the cross-section of bunds become very less over a period of 3-4 years and become useless due to frequent breaching. It has been found at Valsad (Gujarat) that *Dichanthium annulatum, Amphilopsis glabra, Andropogon ischaemum* and *Cenchrus ciliaris* grasses provide excellent cover and good yield of fodder Their elaborate root system acts as soil binder *Panicum repens* and *Penicum antidotale* have excellent root but do not produce good ground cover While *Amphilopsis ordorata* provide poor root system but good ground cover and herbage (Srinivasan et al, 1962) At another North Indian town, *Cynodon dactylon, Dichanthium annulatum, Cenchrus ciliaris,* and *Pennisetum purpureum* have shown excellent results for bund stabilisation, out of various grasses tried.

Stabilisation of active, vertical gully heads

Very deep and vertical gully heads result in under-cutting or caving. Farmers provide natural angle of repose leading to encroachment of valuable table-land which makes the whole operation uneconomical and wasteful. In such circumstances, it is advisable to fill in the cave and face of the gully head up to about two-third height from the bottom and ease up the gully for the remaining top one-third portion of the vertical face. The newly created slope is stabilized by sodding or sowing suitable grasses like *Dichanthium annulatum* or *Cenchrus ciliaris* and constructing a series of small brush-barriers Cutting of active gully head to 1 1 slope has been found cost-effective These measures should only be adopted when vertical and caved gully heads are threatening the underlying structures

Construction of composite checkdams

Design aspect of composite checkdams is important in gully and ravine reclamation The maximum runoff is predicted through rational formula [$Q = CIA/360$], where Q=run-off(cumec), C= runoff co-efficient, I= rainfall intensity (in mm/hr) and A= area of watershed (in ha). The length of spillway is determined by Francis' formula [$Q= 3.33\ LH\ 3/2$] where L= length of weir notch (in m), and H= height (in m) of natural flow above the spillway level. Vertical spacing of checkdams is fixed at 120 cm and horizontal spacing at about 120 m keeping the top of the checkdam at the base of one on its upstream side. Wingwalls are usually constructed on the upstream side. The downstream wingwalls keep length of water erosion as double the length of spillway. The water cushion from the top of curtain wall is kept at around 30 cm.

Retaining walls

Retaining walls are constructed primarily to stabilise hill slopes. These structures are broadly classified as structures subjected to water pressure and those subjected to earth pressure Dams and weirs are basic structures subjected to water pressure. The angle of the soil must be properly considered in the design, when used against earth pressures. The structures must be designed to satisfy the conditions of stability. The stability of a retaining wall is due to the self-weight of the wall, aided by passive resistance developed in front of the wall

Structures subjected to water pressure

Forces acting on one metre length of retaining wall are (i) weight of retaining wall acting vertically downward (W), and (ii) horizontal water pressure (P).

$$W = \frac{a+b}{2} \times H \times P$$

where.

H = Height of the wall
P = Horizontal water pressure
a = Top width of the wall
b = Bottom width of the wall

$$P = WX$$

where

W = Density of water
X = Depth below the surface of water where pressure is measured

$$P = \frac{WH^2}{2} \text{ (pressure acting at a distance} H/3 \text{ above the base)}$$

$$R = \sqrt{p^2 + W^2}$$

where R is resultant force on the wall. Where there is no water, the value of horizontal water pressure (P) is zero. The resultant force is R=W. For the structure to be in equilibrium, the following conditions must be satisfied:

- The algebraic sum of all the vertical forces must be zero, i.e., v=0
- The algebraic sum of all the horizontal forces must be zero, i.e., H=0
- The moment of all forces acting on the wall must be zero, i.e., M =0.

The retaining wall should have safety against sliding and overturning.

In Jhabua, boulder retaining walls have proven efficient and satisfactory. They are very cheap and can easily be tried on locations where the boulders or rocks are easily available. They can be easily constructed along with staggered contour trenches and drainage line control structures. The masonary and concrete retaining walls have been found costly and technocratic.

Structures subjected to earth pressure

The slope of a mass of loose earth thrown upon a horizontal plane will gradually and finally attain a slope of equilibrium. The greatest inclination of the slope to the horizontal at which the earth will stand permanently is termed as angle of repose or angle of internal friction:

$$W = \frac{(a+b)}{2} \times H \times P$$

where:

W = Weight of wall meter length
a,b = Top and bottom width of the wall
H = Height of the wall
P = Horizontal water pressure

$$P = \frac{WeH}{2} \times \frac{(1 - \sin 0)}{(1 + \sin 0)}$$

where:

P = Density of the masonary (kg/cum)
We = Density of earth (kg/cum)
H = Height of the wall (m)
0 = Angle of repose of earth (degrees)

Sediment retention structures

These structures trap eroded soil before it can reach a water body, especially in transition and discharge zone of the watershed. Sediment retention devices should be used only as back-up support systems, if preferred methods like vegetative barriers, etc., fail or if no other measures are feasible Also, they can at best give temporary solution until permanent measures are in place

These structures slow the velocity of runoff and let the suspended soil particles settle by gravity Some of the commonly constructed structures are straw dykes, filter fabric fences, sediment traps and sediment basins These structures have numerous weaknesses and the efficiency of the system is dependent upon the clay and silt fraction. Watersheds with high clay and silt proportion in soils require large basins to capture the eroded soil. A retention structure should be typically designed with a removal efficiency of 50-75% Even the most efficient structure cannot trap all the eroded soil and almost half of the eroded soil passes through the tank. These sediment retention structures need maintenance and repair at regular intervals. Excess deposition of silt or sediment will accumulate in the basin which over a period of time cease to function. These trapped sediments will not settle but remain suspended, and can be washed away.

The most commonly used sediment retention structures are sediment basins and traps, in which soil particles settle through water under the influence of gravity. Sediment basins are larger than sediment traps and they are more precisely designed. Goldman et al developed a simple model of an ideal sediment basin in 1966. The soil particles are assumed to have uniform density and move horizontally with uniform flow in one direction with the water through the basin at velocity of Q/WD. A flow Q (m^2/sec) enters a basin of depth D, width W and length L The particle will fall at a vertical velocity of Vs. The time for the particle to traverse the length of the basins will be

$$To = \frac{L}{Q/WD}$$

The time for the particle to fall to the storage zone Tv, will be:

$$Tv = \frac{D}{Vs}$$

Setting the transit and falling times to be equal, we get

$$To = Tv = \frac{D}{Vs} = \frac{L}{Q/WD}$$

$$VsL = \frac{DQ}{WD} \quad \text{or} \quad Vs = \frac{Q}{WL}$$

$$WL = \text{basin surface area} = \frac{Q}{Vs}$$

More appropriately $WL = \frac{1\ 2\ Q}{Vs}$, where 1 2 is a constant

$$As = \frac{1\ 2\ Q}{Vs}$$

where.

As = Appropriate surface area for trapping particles of a certain size

Vs = Setting velocity for that size of particle

Turbulence, short-circuiting, bottom scour, riser design, wind and temperature affect the performance of the sediment retention basins The ideal basin efficiency corresponds to the percent of soil equal to or larger than the design particle size If a sediment basis is designed to capture 0 05 mm particles and 73% of the particles are greater than or equal to 0 05 mm, the maximum efficiency of the basin is 73% The efficiency can be increased by increasing the surface area of the basin. It should also be kept in mind that the required surface area increases very rapidly as the particle size decreases (see Table 12 3).

Table 12.3 *Surface area requirement of sediment traps and basins*

Particle diameter (mm)	*Setting velocity (m/sec)*	*Surface area requirements (m^2)*
0 5 (coarse sand)	0 058	20 7
0 2 (medium sand)	0 020	58 7
0 1 (fine sand)	0 0070	171 0
0 05 (coarse silt)	0 0019	635 0
0 02 (medium silt)	0 00029	4101 0
0 01 (fine silt)	0 000073	16404 0
0 005 (clay)	0 000018	65617 0

13

Water Conservation and Harvesting

Most of the land under cultivation in India is dependent on rainfed conditions. Production in such areas can be stabilised and improved by water conservation and harvesting structures to control *in situ* moisture content Low rainfall areas have frequent dry spells causing severe damage to the agricultural operations and productions Even in case of high rainfall areas, dry spells within the monsoon period may cause fluctuation in crop production Flooding due to heavy downpour may result in water loss with concomitant losses. It is thus practical to develop integrated water conservation and harvesting structures to mitigate droughts and moderate floods They also harvest the runoff water and store and recycle it for stabilisation of agricultural productions

Irrigation tanks in India have been constructed for many centuries. Earlier, the communities would construct such irrigation tanks with financial or technical support from outside The collective wisdom of the community was instrumental in construction of thousands of irrigation and *nistar* tanks in central, western and south India The village experts in the name of *Gajdhar* (known by numerous names in different regions) were responsible for construction, follow-up maintenance and management. With the emphasis shifting on large projects and government-sponsored big dams, consequential neglect of community-assisted tank construction was pushed to relative insignificance The Integrated Watershed Development Programme highlights community participation in small water harvesting structures Water harvesting may be considered in terms of·

(1) type and quantity of storage (small amounts for domestic use or large quantities for irrigation below ground in cistern or above ground in tank structures);
(2) purpose of water storage(domestic use/stock watering/supplementary or complete irrigation); and
(3) whether the catchment has been treated for reducing the runoff or is in its natural state.

Design and location of such structures in a watershed area needs a lot of attention. Another important factor is the amount of water required, calculated from daily consumption or crop requirement Frequency, intensity and duration of rainfall alongwith surface conditions affect the water runoff They should be estimated before designing the structures. The losses from stored water through evaporation, seepage and leakage should also be estimated.

Water harvesting and recycling has following constituents. (a) collection and harvesting of excess rainfall, (b) efficient storage of harvested water, (c) water application, lifting and conveyance, and (d) Optimum utilisation of applied water for maximum benefits. Water management system in a watershed may be streamlined into three-tier system (Dhruva Narayan and Pande, 1976)· (1) Collection of part of the rainfall in the crop land until such time and extent as will not be harmful to the crop. (2) Directing the excess water after storage from various parts of the catchment in the lowest portion of water harvesting structure. The stored water is utilised for irrigation in adjacent land during the dryspells. (3) Remaining excess water is discharged into regional drainage system.

Water conservation methods in agricultural land

The techniques for water conservation in agricultural land requires localised surface storage and may involve substantial inputs of cost and energy in reshaping the soil and sub-soil surface.

The cropping pattern used in agricultural land in watershed areas should be such as to ensure perennial use of the available water resources and moisture and maintain the fertility of the soil Surface, sub-surface and groundwater resources should be maximally exploited and wherever possible should be used conjunctively. Groundwater resources can be used to provide supplemental irrigation for sowing the crops at the right time or for proper ripening of crops in case there is scanty rainfall at final stages The rainfall pattern and soil type should be taken into account Cropping pattern, alongwith water management schedule, should be worked out This, when cautiously implemented, will ensure maximum and efficient use of water. Improper application, irregular distribution and deep percolation may lead to as much as 30-35% losses The remedy lies in scientifically planning the project, efficient distribution network of water as needed, growing the right varieties/species of crops in appropriate manner and providing for good drainage of agricultural lands Lining of field channels and water courses, underground pipe conveyance systems and latest water harvest techniques may prove to be effective soil and water conservation measures Depending upon the type of soil, the slope of land, the kind of crop and the availability of water/moisture an efficient irrigation system should be evolved. Various options like flooding, flat bed, strip and border strip, ridge bed, furrow drip, contour ditch and basin irrigation systems are available.

Border irrigation

In this method, a thin sheet of water advances down the narrow strip between line ridges and water infiltrates into the soil as the sheet advances The border is usually adopted where topography permits precise land levelling at the reasonable cost and where enough water for irrigation is available. The width and length of each border strip varies from 4 m x 30 m for sandy soils to 15 m x 300 m for clayey soils The strips are separated by small land 0 15 m high The land is graded smoothly along the natural slope (0 1-0 6%) in the direction of irrigation with no cross slope Border irrigation is recommended for gentle slopes Close growing crops like wheat, barley, *bajra, barseem* and row crops like cotton, maize, *jowar* and sugarcane are preferred.

The advancing sheet of water should be adjusted so that there is enough time for the water to soak into the soil to replenish the soil moisture reservoir. When the required depth of water has been applied, the stream is shut-off and diverted to another strip.

Maximum area that could be covered by the stream:

$$A = S/I$$

where

S = Size of stream
I = Infiltration rate

A unit stream, frequently used in border irrigation, is the size of the stream required to irrigate 100 m of border area, i e., an area 1 m wide and 100 m long. The border method of irrigation is now prevalent in parts of Karnataka and other South Indian states. Recommended dimensions for border strip are below given in Table 13 1:

Table 13.1 *Recommended dimensions for border strips*

Soil type	*Optimum grade of border (% slope)*		*Size of stream q lps*		
			30	*30 to 50*	*50 to 100*
Sand	0 4-0 5	W m	6-10	10-12	10-12
		L m	60-100	100-120	140
Loam	0 2-0 3	W m	8-10	12	12
		L m	80-120	140-220	140-220
Clay	0 05-0 1	W m	10	12	15
		L m	140-220	220	220-300

Furrow irrigation

Furrow irrigation is suitable for cultivation of row crops like maize, sorghum (*jowar*), sugarcane, cotton, groundnut, tobacco, chillies, potatoes, orchards and vegetables The water is applied in furrows between crop rows and water soaks into the root zone of crops. The spacing of furrows is usually decided by the spacing of crop rows and ranges from 0.6 to 1 2 m Furrows should be close enough. The furrows may run down the slope when the slope is within reasonable limits (0.7-1 0%) It may be laid across the slope or on the approximate contour, to reduce grade and prevent erosion on steeper slopes Furrow grades of 0.3-0.5% are found satisfactory. The land must be graded so that the water moves down the entire length of the furrow without ponding. Short tubes of 3-5 cm diameter of metal, wood or rubber may be used for letting in water into the furrows from the channels Furrow size (depth x width) varies from 0.15 m x 0 25 m to 0 30 m x 0 60 m The size of the stream depends on the type of soil, slope and the length of run The length of run depends upon the infiltration capacity of the soil, the size of the stream, the root depth of the crop and furrow gradient. The water should run in the furrow till the desired penetration is achieved. The time required for irrigation in furrow stream is.

$$t = \frac{L \times w \times d}{10\,S}$$

where:

t = Time of irrigation (min)
L = Length of furrow run (m)
w = Furrow spacing (cm)
d = Net irrigation application (cm)
S = Average furrow intake rate (lpm) of furrow stream

Table 13.2 *Furrow streams in lpm*(after water has reached the end of the furrow)*

	Soil infiltration rate								
	High > 4 cm/hr			*Medium 1.5-4 cm/hr*			*Low 0.25-1.5 cm/hr*		
Length of run(m) *Land slope*	*100*	*200*	*400*	*100*	*200*	*400*	*100*	*200*	*400*
0.02	40	90	200	18	45	112	9	18	40
0.2-0.5	18	40	90	14	30	70	7	16	35
0.5-1.0	14	30	70	7	15	35	4	9	18

* With furrows, initial flow rate will be 2-3 times the indicated rate to fill the run as quickly as possible and then the flow cut back to the indicated rate. The furrow stream should reach the lower end of the field within one-fourth of the total time required for irrigation

With level furrows, the initial stream is continued till the end of irrigation.

Corrugated irrigation

The corrugated method is an adoption of furrow irrigation for heavy soils, small streams and close growing crops. Corrugations are shallow furrows and are close enough, so that the moisture is obtained both by capillary action and gravity The spacing vary from 40 cm for sandy soils to 60 cm for heavy soils Corrugations are 10 cm deep and 12-15 cm wide. The length of corrugations vary from 100 m to 200 m

In this method small ridges are made on the bed with opening at alternate ends and the crops are planted on both the sides of the ridges Water is entered in the proximal higher end and it passes through the furrows in a zig-zag fashion When it reaches the lower end of the plot, the supplies are cut-off Enough time is provided in this system, for water to percolate into the soil The field efficiency of this system is around 70% for slopes with less than 0.5% gradient The efficiency decreases with increase in slope. This method has been found to be appropriate for almost level plots for raising potatoes and turmeric

Broad bed and furrow system (BBF)

This system has following objectives.

(a) to encourage moisture storage in the soil profile;

(b) to safely dispose of surplus surface runoff without causing soil erosion,
(c) to provide a better drainage and more easily cultivated soil in the beds; and
(d) to re-use runoff stored in small water harvesting structures.

This system consists of broad beds about 1 m wide separated by sunken furrows about 0.5 m wide. The system has proved effective in slopes along the furrow between 0.4% and 1.0% cm heavy, black, clayey soils (cotton soils). Two to five rows of crop can be grown on the broad bed, and the bed width and crop geometry can be varied to suit the cultivation and planting equipment. In India, wide beds are used on gentle gradient under this system of agriculture. The resultant moisture storage upto 250 mm may be sufficient to support plants through spells of dry conditions. Double cropping may become possible due to intercropping or sequential cropping.

There is a very narrow range of moisture conditions during which the soil can be properly tilled Selection of proper time for tillage operations is a crucial factor Around 25% of deep black-cotton soil areas are cropped during the rains, fundamentally due to poor workability conditions So, it should be tried to establish crop during the early rains. Tillage operations may be possible before the rains, creating possibility of dry seeding ahead of the rains in areas where there is reliability regarding the onset of the rains The difficulty in preparing seed bed during the dry season in these hardy soil conditions may be overcome by using animal driven or mechanical equipments It is important to remember that small amounts of life-saving irrigation application in dry season may be very useful on soils with lower moisture storage capacity

The BBF system works most efficiently on deep black soils in areas with dependable rainfall averaging 800 mm or more The system, proves less than sufficient in areas with less dependable rainfall or with shallower black soils The BBF system should not be considered in isolation, and should always be applied with improved farming methods and techniques

Contour furrow

It is also termed as contour bunds and desert strip farming These do not require much manipulation in soil surface They are more frequently adopted by small farmers or in lower rainfall areas Essentially, in this system, cropping is usually intermittent on strips or in rows and the intermittent catchment area is left fallow. The philosophy behind the approach is to collect runoff from the catchment to improve soil moisture on the cropped area Studies by Smith and Coitchley in 1983 have indicated that with a catchment ratio of 2 1, a satisfactory sorghum (*jowar*) crop can be grown in 270 mm of dismal rainfall On heavier soils and black cotton soils, contour bunds may be less effective because of lower infiltration rate The biggest disadvantage in using this system is that only a very small part of the total field can be cropped But, nonetheless, it ensures some bit of cultivation in areas and conditions where cropping is unthinkable.

Similarly, a large number of separate semi-circular or trapezoidal bunds may be effectively used to store surface water flow. They also decrease the risk of damage from overflow in even exceptionally heavy rains Both types of conservation techniques show best results on gentle slopes (especially trapezoidal bunds which show best results with 1 5% gradient). The trapezoidal bunds can encircle areas from 0.50 to 2.5 ha More productive areas should be selected. They can be levelled within the bund to ensure more uniform spreading of the retained water. One shoulder of the land should be slightly lower to serve as an overflow spillway These shoulders should be protected with simple boulder paving. Both types can be staggered on alternate rows, so that the overflow from one row will run into the next down slope. The land may be shaped by ploughing. In low rainfall areas, a large ratio of catchment to cropped area is required. But it is not easy to design a system in which this ratio can be reduced without affecting the productivity and production for all variations of annual rainfall Shanan and Tadmor (1979) found that the best ratio of catchment to cropped area could vary from 4 to 20.

Ridging and tied ridging

This method is also known as *furrow blocking* and *basin listing* The system involves making ridges and furrows, then damming the furrows with small mounds or ties which increase surface storage. Tied ridges decrease the runoff and increase the storage Graded ridges on the other hand usually lead to an increase of surface runoff. Either changes in designs will ensure drainage or storage as needed in a particular field condition Even in a best designed system, opposite results may arise, rather than expected results in a particular season. Tied ridging is generally associated with mechanised farming and sprinkler irrigation. During high rainfall years or in years when relatively long periods are wet, lower yields were reported from systems with tied ridges, than with graded systems which disallow surface collection of water Tied ridging tend to enhance waterlogging, anaerobic conditions in rooting zone, fertiliser leaching, etc. Thus, tied ridges have shown better results in drier conditions as compared to high rainfall areas/periods.

When ridges are broken due to the force of collected water, the sudden release of water temporarily stored in the depressions may cause soil erosion High value of soil storage, good infiltration and permeability may be required to overcome this. The infiltration may be increased by mulching, sub-soiling or cultivation To avoid damage to tied ridges, the furrows should be constructed on a gentle slope to assist runoff if the tied ridges fail The ties should be kept lower in height than the ridges, so that the ties fall along the furrows There should be a back-up system of conventional graded channel terraces to prevent damage if the ridges do overtop or fail

Inundation techniques

In arid and semi-arid regions of India innumerable inundation techniques have been used for past many centuries The system involves integrated water control and land management techniques. Such *ahars* are frequently seen in arid and semi-arid regions Low earth bunds are built to retain runoff during the monsoon. When used on very gentle slope (0 01%), water stored to a depth of one metre will throw back several kilometres which can cover large areas of land Some *ahars* may flood as large an area as 600 ha The volume of water stored is relatively less important than the area of land which is submerged. The soil must have sufficient depth and moisture-retention capacity to store enough moisture for *kharif* and *rabi* crops The retaining bank is usually not more than 3 m high and may extend several kilometres on the contour Usually, a wide waste-weir is constructed and stone pitched with crest level 1 m below the top of the bund, gives 1 m freeboard for wave action. It is essential to provide metal sluice gates set in concrete structures to allow for quick emptying when necessary The water released from one *ahar* may be collected in the next *ahar* down the slope. The main crop winter wheat is planted as soon as the flooded land has dried out sufficiently and a subsidiary variety of rice may be grown in the standing water.

Small storage structures

Small storage structures have immediate (perceivable) and direct benefits Some of the objectives performed by these structures are long-term and indirect These structures are instrumental in maintaining moisture for long duration and provide storage water for utilisation. These structures are very important in an Integrated Watershed Development Plan These structures perform multiple functions like:

1 to intercept runoff and moderate peak flow and volume,
2 to improve absorption of available rain water thereby improving general moisture conditions,
3 to enhance and accentuate groundwater recharge,
4 to improve dry weather flow in bigger streams and ensuring perenniality of main *nallas* and medium streams,
5. to intercept and reduce silt and sediment flow and reducing sediment production in the stream and deposition in the reservoir,
6 to provide irrigation potential to farmers in *rabi* and *kharif* seasons,
7. to help in levelling undulations or eroded gullied areas,
8 to help in reclaiming additional productive land,
9 to provide more remuneration by creating environs for additional crop and provide additional job avenues to the rural poor,
10. to create additional opportunities for employment like tree plantation, duckery, etc ,
11 to increase CPR base in the region, and
12 to increase total resource base in the watershed

It is difficult to classify these structures in various categories. They can be classified on the basis of the primary function they perform regarding protection of upstream areas, trapping of flowing sediments, creation of water points for human settlements and grazing cattle, water harvesting for groundwater recharge or for irrigation, etc

The most common structures are embankments, spillways and farm ponds These spillways could be chute, drop or drop-inlet spillways. Water storage behind these structures are provided with outlets and sluice-gates to regulate water flow Water could directly be used by lifting water from the tank or it can be spread out in *nallas* from which the water can be used for irrigation in small areas These structures help in greater absorption of water on larger areas and also hold some in dry spells They help in coping water shortage during dry spells and create more vegetation which act as a lasting protection against extreme drought conditions Pipe outlets, grassed water ways, etc., may be used to take water to the distant outfields

Planning for a storage structure is a very elaborate exercise Lot of information should be collected before undertaking the construction activity (also see Plate 34 a, b)

Plate 34 (a, b) *Earthen embankments on farm ponds depend on the site conditions, edaphic conditions and proposed objectives Earthen embankments constructed for irrigation should have optimal capacity*

Chart 13.1 *Informations to be collected before undertaking the construction activity*

(a) General data

(i) Location data
- — location of the structure
- — existing location of roads
- — catchment and command area
- — contour maps of the location
- — stream gauging and groundwater bench marks

(ii) Hydrological data
- — stream flow records including flow volume and rates
- — stage-discharge curves for streams
- — flood studies
- — water requirements including conveyance losses seepage percolation, evaporation losses etc
- — sedimentation including sediment measurement, etc
- — data on groundwater table
- — cross-section of streams with dated water surface elevation

(iii) Geological data
- — soil infiltration rates
- — geological strata
- — lineaments and fractures
- — geological data about formation, exposed gravel deposits of permeable nature
- — geological cross-sections

(iv) Climatic data
- — evaporation rates
- — monthly rainfall and temperatures
- — maximum, minimum and mean temperatures
- — wind direction and velocities

(b) Reservoir data

(i) Reservoir map
- — topography
- — horizontal and vertical controls
- — ownership boundaries of adjacent plots
- — dimensions of catchment areas and command areas
- — linkage of the site with transport facilities(roads)
- — submergence area map (demographic and botanical survey of the submergence site)

(ii) Miscellaneous data
- — estimation of probable silting and life of reservoir
- — tabulation of areas to be cleared, with approximate costs
- — description of lands adjacent to the proposed reservoir
- — listing and description of proposed beneficiaries
- — discussion of limitations to reservoir fluctuations

Contd

Chart 13.1 *Contd*

(c) Data for dams

(i) Dam site data

- topography of dam site
- horizontal and vertical controls, preferably by a triangulation system
- coordinate system grid
- location of rock outcrops and geological features
- location of drill-holes, test pits and foundation exploration sites

(ii) Foundation and material exploration

- description and log tables of exploration
- characteristics of bedrock of impervious foundation strata for feasibility study and specifications design
- series of drill holes, auger-holes, testpits to determine character and depth of overburden for feasibility study and specification design
- representative samples of materials in borrow areas
- location, description of character of proposed material to be used in construction
- map of borrow areas
- availability map for input materials
- storage hut at the site for materials

(iii) Tailwater data

- tailwater and backwater curves
- stage-discharge curves for streams
- cross-sections of streams

(iv) Miscellaneous data

- capacities and elevations of required outlets as determined by local conditions
- estimated cost for transportation of materials
- requirements of water-supply, electricity-supply at the site
- requirements of manual labour and TNP at the site etc

The procedure of collection of the data may be intricate and time-consuming and it may not be possible and practical for small storage structures in watershed areas Thus, not much time should be wasted in collection of such data and information

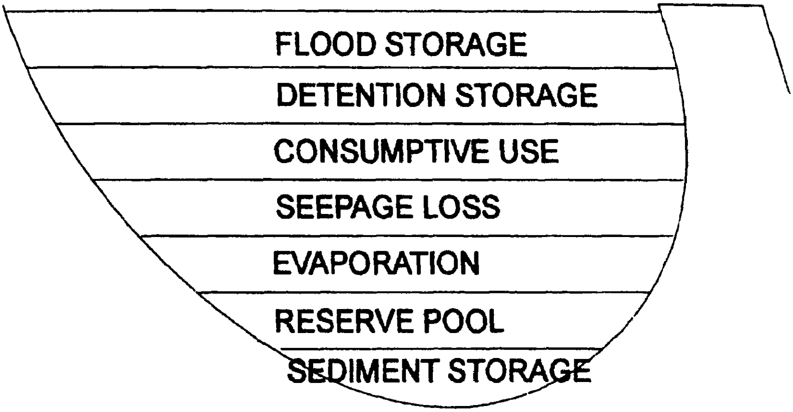
Earth embankments

In designing and constructing earth embankments for farm ponds, irrigation reservoirs and grade stabilisation structures, numerous factors should be considered These are quite commonly constructed structures and are economical and effective on suitable sites

(a) *Defining objective of the earth embankment* The purpose of the structure should be defined very clearly so that design requirements can be identified For example, when the purpose of the structure is irrigation, the required amount of storage is defined, and also the period when the water must be available

(b) *Site investigation* The suitability of a pond or reservoir site is dependent on the ability of the soils in the area to hold water and provide a stable foundation for the embankment In areas where the nature of the soil is such that permeable or unstable materials may be present in the soil profile, a geologic investigation should be made to determine, if a satisfactory structure can be built at that site. Soil borings or test pits should be made at intervals over the structure site. The frequency of the borings depend on the occurrence of significant changes in the soil profile. The boring should be made to sufficient depth to identify material that may be unstable or may affect the ability of the structure to hold water. If undesirable material is encountered, another site should be considered or the undesirable should be areas given special treatment. From an economic point of view, the reservoir should be located where the largest storage volume can be obtained with the least amount of earthfill. Suitable location could be a site where the valley is narrow, side slopes are relatively steep and the slope of valley floor permit a large deep basin. Generally, large areas of shallow water should be avoided due to excessive evaporation losses and the growth of noxious aquatic plants Structures proposed to be used for irrigation should be located closest to the point of use (see Figure 13.1)

Figure 13.1 *Reservoir with various design volumes*



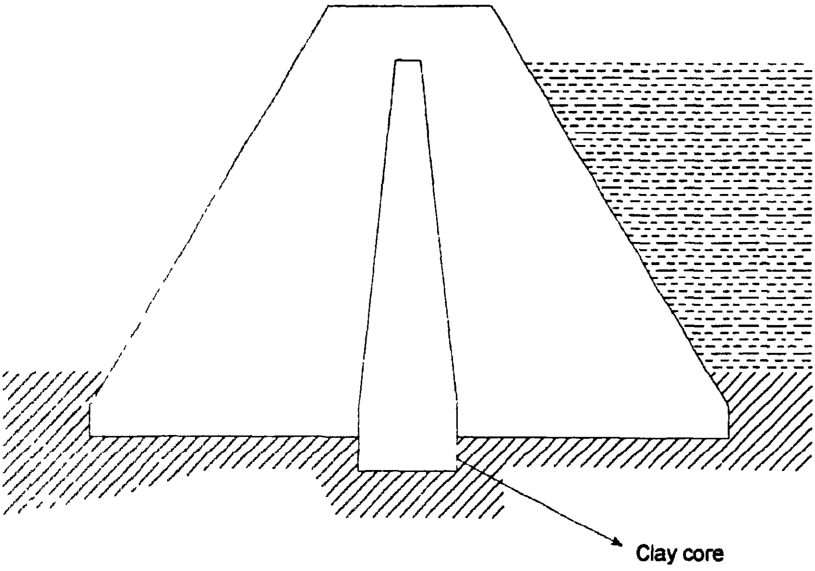
(c) *Capacity* The capacity of the structure depends upon the principal function envisaged, demands and their fluctuations, losses estimated from evaporation, seepage, etc The shape of the valley and slopes of the side walls determine the storage capacity of the structure for the given height The ideal site has a long throwback and has steep valley sides at the embankment

(d) *Soils* The site must have suitable soil conditions for constructing an earth dam The soil of the basin should not be porous Saline, alkaline or sodic soil, soils high in organic matter, soils containing a high proportion of fine silt, light soils and heavy clay soils are supposed to be unsuitable for dam construction

(e) *Preparation of site and borrow area*: All trees, stumps, trash, brush sod, large roots, perishable material and loose soil should be removed from the site and borrow areas. Topsoil is stripped from the embankment foundation and borrow areas and deposited in storage piles. After the stripping operation, the ground surface within the foundation area is scarified to provide a bond between the foundation and earthfill Overhanging banks, pits and holes within the foundation area are graded to a one-to-one or flatter slope to provide a bond with the fill The borrow pit should ideally be located upstream from the toe of embankment to increase the depth. A minimum of 0.6 m of impervious strata is considered sufficient.

(f) *Core trench construction*: The core trench is excavated to the extent and dimensions necessary to prevent any possibility of seepage under the embankment. Side slopes are constructed one-to-one or flatter The most impervious material available at the site is used to backfill the core trench The moisture content of the backfill material should be sufficient to secure proper compaction The trench must be kept free of standing water during backfill operations (see Figure 13 2).

Figure 13.2 *An earth dam with an impermeable clay core*



(g) *Installation of blanket* Pond basins containing a high percentage of coarse-grained soils may require a blanket of less permeable material to prevent seepage At some locations the topsoil may be less permeable than the subsoil The less permeable material in the area should be stockpiled and spread as a blanket over the more permeable material *in the pond basin The blanket should be placed in 4-inch well-compacted layer to a* minimum thickness of 12 inches If a blanket is used over the entire pond basin, core trench is not required

It is very difficult to construct big enough structures which can store all the runoff. Some essential provision is required to pass on the surplus flood water after the dam is full The spillway is the channel or waste-weir designed to perform this function Concrete and masonary spillway may cost a fortune, hence only those sites should have earthen embankments where cut or natural spillways allow excess runoff water to be discharged into grassed waterways (see Figure 13 3 a, b)

Generally, spillway requirements can be classified into four categories low flows and short drops, high flows and short drops, low flows and long drops, and high flows and long drops The least expensive class is low flows and short drops and the most expensive is high flows and long drops Most economical yet stable option should be selected for a given flow and drop requirement Commonly used spillways are described below:

Principal spillways

(a) *Pipe* A pipe spillway consists of a closed conduit with an inlet designed to cause the conduit to flow full with a relatively low depth of water over the entrance and all the opportunities necessary to provide a safe structure (see Figure 13 4 a, b) It may be used to discharge water directly from diversions, grassed waterways or other channels into a main drainage way The structure may be constructed with no provisions for permanent water storage behind the structure and very little detention storage above the spillway inlet The outlet end of the conduit is usually placed above the expected water level The bank of the drainage way is sloped so that the conduit does not protrude into the channel Pipe spillways are also used in conjunction with earthen embankments to carry water from above the embankment to a lower elevation The conduit would flow full and a greater capacity would be obtained if a depth of flow over the inlet is equal to five to seven times the diameter of the conduit Conduit with the end cut off-square is quite commonly used. Canopy-inlet, hood-inlet, drop-inlet and morning glory-inlet are few of the modifications. In general, pipe spillways are well adopted to sites where a good emergency spillway or an appreciable amount of detention storage can be provided to control overfalls greater than 3 m If high rates of flow are to be carried, a suitable emergency spillway cannot be constructed, and there is limited detention storage, a large diameter conduit will be required. which is expensive In such situations, chute or drop spillway may be used

(b) *Weir* The straight drop spillway is a weir structure Flow passes through the weir, drops to an approximately level apron or basin and then passes into the downstream channel It may be constructed of reinforced concrete, rock masonary, concrete block, steel, timber piling or pre-fabricated metal The straight drop spillway is well adopted to the control of overfall upto 3 m, where large rates of flow must be handled and an appreciable amount of detention storage cannot be provided These structures can only be constructed where there is sufficient area of nearly level land on either side is available to carry the overflow without damage to the crop or the land The straight drop spillways perform following functions grade control in stabilisation channels, outlets for surface water into drainage ditches, protection of the outlet end of a grassed waterway The structure usually is stable, if properly designed and installed, and it is not likely to be clogged by debris The straight drop spillway requires a stable grade below the structure and is not a suitable structure if detention storage is needed

(c) *Culvert box-inlet* This structure is constructed by placing a box-inlet drop spillway

Figure 13.3 (a) *Installation of an outlet pipe under a damwall*

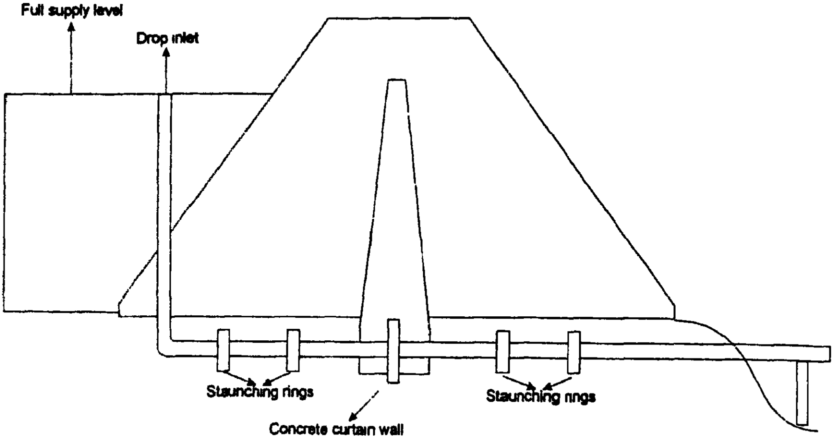


Figure 13.3 (b) *A reservoir with a pipe and an emergency spillway*

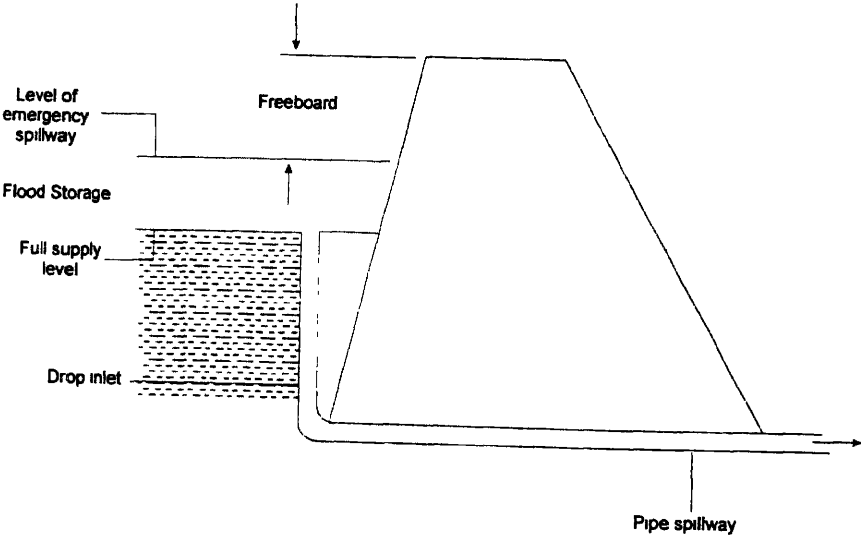


Figure 13.4 (a) *Pipe spillway to discharge water into a drainageway*

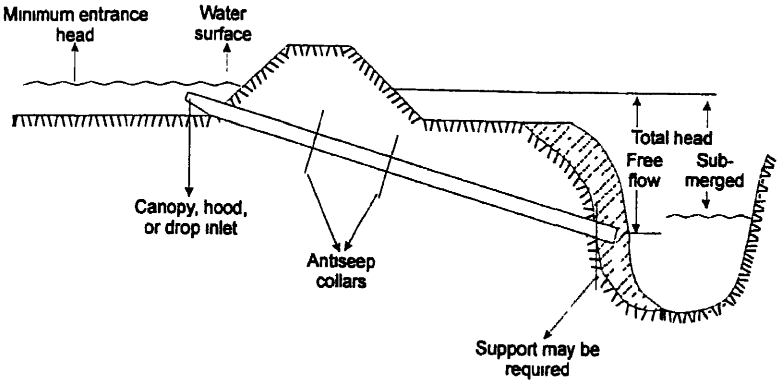
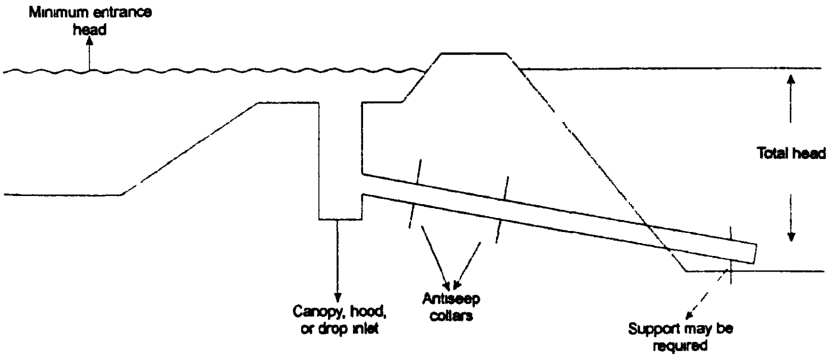


Figure 13.4 (b) *Pipe spillway to discharge water impounded behind an embankment built into a weir bench*



at the upstream end of a culvert. It may be built as integral part of a new culvert or it may be fastened to the upstream headwall of an existing culvert The culvert box-inlet controls gradient above culvert in either a natural or constructed channel, controls gradients and reduces erosion in the ditches and can be used as a cattle pass. The structure is very economical for controlling overfalls If the culvert is of concrete, then the box inlet may be constructed of reinforced concrete, plain or concrete blocks Corrugated metal box-inlets are used if the culvert is of corrugated metal The common and most preferred principal spillways in an earthen embankment are cut spillways and natural spillways These structures have shown promising results in Integrated Watershed Development Programme in Jhabua

(d) *Cut spillways* For small conservation dams, open channel spillways cut into the bank at the side of the embankment wall are sufficient These structures are cheap and quite effective There is a risk of soil and water erosion if the water flow is very quick Required size of a spillway may be reduced by maintaining a good grass cover Anyway, maximum size of catchment for dams with grassed spillways should be limited to 500 ha To prevent erosion at the junction of water and stream, the stream bank must be cut back to a gentle slope and should be densely covered with grasses The structure should be avoided in streams which are likely to have constant flow or have flow for a considerable duration as the grasses might not be able to cope with excessive moisture conditions The structure in such case may be protected by a small brick-lined or concrete channel set in the spillway or by a small diameter pipe going through the dam wall preferably on the opposite side of the stream from the spillway The most vulnerable parts may be protected with stone pitching or concrete

(e) *Natural spillways* Sometimes the existing conditions permit diversion of flood flow into a naturally existing waterway or channel The runoff is turned into a separate crest The slope down to the stream should be gentle and should have enough grass cover, so that risk of erosion can be taken care of

Emergency spillways

Emergency spillways are provided to convey the design flow around a structure at a non-erosive velocity to a safe point of release These spillways may be used in conjunction with ponds, irrigation reservoirs and stabilisation structures, with earth embankment structures, that provide an appreciable amount of detention storage or with full-flow structures that provide little detention storage For structures constructed in less favourable conditions, a principal spillway can be used to carry the low rates of runoff and an emergency spillway should be placed above the principal spillway to carry the balance The emergency spillway should have the capacity to carry the runoff resulting from the peak outflow reduced by the discharge carried by the principal spillway The control section is constructed to a trapezoidal shape with three-to-one or flatter side slopes Minimum width of all control sections should be 10 ft Generally, control section should be constructed as wide as possible The cost of construction of wider control section is usually less. This also enables shallower depth of flow at a lower velocity and less fluctuation in the water level The section below the weir or control is designed as a waterway Emergency spillways for earth embankment structures usually consist of an approach channel, control section and exit-section Generally, the excess runoff from the control section must be discharged on to sloping terrain below the structure, in which case a grassed waterway or a diversion channel should be provided as an exit section. If the land slope below the control section is not too steep, the runoff may be discharged into a grassed waterway of approximately the same width as the control section If the slope is steep, the waterway will be much wider The runoff from the structures may be routed into a diversion channel and carried to a location at some distance from the embankment Some times, flow from an emergency spillway may be discharged onto the natural slope The vegetative cover in the area, onto which the emergency spillway discharges, should be handled carefully.

The following minimum top widths are suggested for dams of various heights: with a height of under 10 ft the minimum top width should be 8 ft; with a height of 10-20 ft, the minimum top width should be 10 ft; and with a height of 21-30 ft, the minimum top width should be 12 ft. If the top of the embankment is to be used as a roadway, the top width should be at least 12 ft

Unnecessary width will add to the volume of earth work required Following formula is commonly used to calculate the width of the embankment

$$W = \frac{H}{5} + 1\ 5$$

where·

w = Crest width (m)

H = Height of embankment above stream-bed (m)

The side slopes on the settled embankment should not be steeper than 3 1 on the upstream side and two to one on the downstream side Soil close to grain sizes, carefully placed and well compacted could have a side slope of 2 1 upstream and 1 5 1 downstream Soil which are difficult to be compacted should have slopes 3 1 or 4 1 The slopes do not make much difference to the overall cost estimates, especially in case of small structures, so a flatter slope is recommended (Table 13 3).

Table 13.3 *Recommended side slopes for earthen embankments*

Soil classification	*Slope (horizontal to vertical)*	
	Upstream	*Downstream*
Well-graded gravels, sand, gravel mixtures	Pervious and hence not suitable	
Clay gravels, silty gravels, gravel sand clay mixtures and gravel sand silt mixtures	2 5 1	2 1
Sandy clays, silty clays, lean clays, inorganic silts and clays	3 1	2 5 1
Inorganic clays of high plasticity and inorganic silts	3 5 1	2 5 1

Flatter slopes should be used, if necessary,to ensure the stability of embankment On the downstream side flatter slopes are also desirable if mechanical equipment is to be used for maintenance. A 4 1 slope is recommended when machine operations are to be performed

When the surface area of the reservoir exceeds 5 acres, extra precaution should be taken to reduce damage caused by wave action Several methods may be considered, 9 ft berm can be constructed on the upstream face of the embankment 0 5 ft above the crest of the principal spillway, a portion of the upstream slope of the embankment can be riprapped, or the upstream slope of the embankment can be constructed to a 4.1 slope Suitable grass or aquatic plants may be used to protect berms from wave action.

Seepage through or under the dam wall should be prevented or reduced to acceptable limits. The central core of the dam should be either constructed with impervious material or a central impermeable core of compacted clay The core should be more than one metre wide The impermeable core must be taken down to, and bedded into, an impervious layer, so that there is no risk of seepage below it. It must also be continued upto slightly above the full supply level along the whole length of the wall and at both ends The material used for the core must have enough clay so that it is plastic and workable when wet. Sandy clay is preferable for small dams The material must be placed properly and compaction should be performed The clay should be placed in thin layers and puddling it by adding sufficient water Compaction may be performed by ramming it with poles (see Plate 35 a, b).

Sufficient overfill should be provided during construction to allow for settlement The material is placed in a 6-inch layer at a moisture content sufficient for good compaction For average soil with reasonable compaction 10% should be added to the finally required height The wall should be constructed in slightly convex fashion along the top as the settlement will be greater in the middle than at the ends

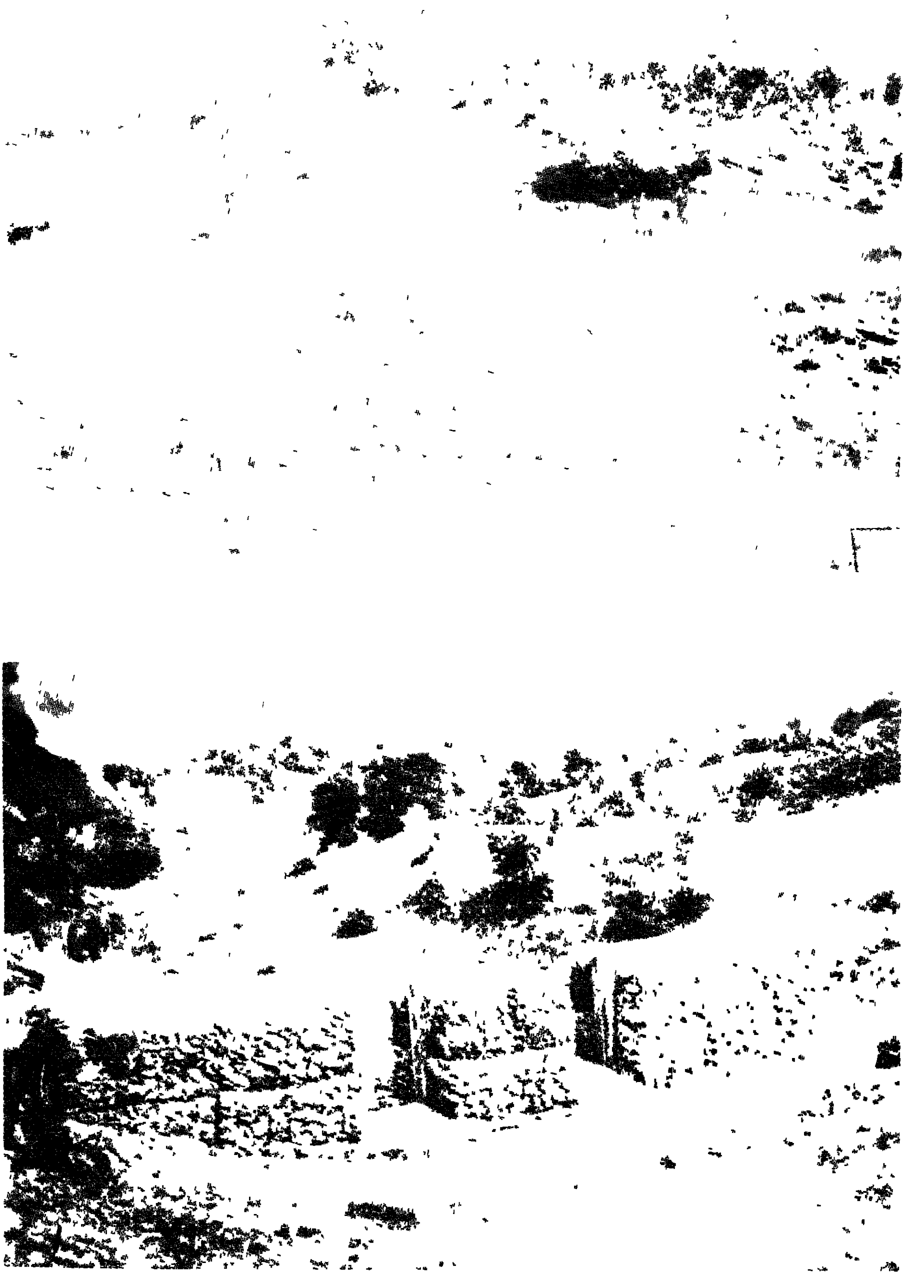
The top of the embankment should be constructed high enough to prevent waves or runoff from storms greater than the design frequency from overtopping the embankment Freeboard is the difference in elevation between the water level in the reservoir when the spillway is flowing at the design depth If both principal and emergency spillways are used and the reservoir is less than 660 ft long, a minimum freeboard of 1 ft should be provided If only an emergency spillway is used, add 0.5 ft to the minimum freeboard suggested above.

A tentative location for the embankment is selected and a row of stakes is set, marking the proposed location of the central line The shape required to store the greatest volume of water for the amount of earth moved will vary from a straight embankment constructed across a relatively deep depression to one semi-circular in shape constructed on a relatively uniform shape A tentative location for the waterline is selected and a series of stakes set at this elevation The area is enclosed by these stakes and by a line marking the intersection of the water level and thus the embankment is determined If this surface area does not equal that desired, the water level stakes may be raised or lowered or the location of the embankment may be shifted to give the size of pool desired

The design runoff to be expected from the drainage area is computed The spillway size and the depth of water expected during the design runoff is determined. The desired freeboard is added and the elevation of the top of the embankment is computed Fill material must not contain any appreciable concentration of vegetation, roots, large rocks, frozen soil, or other foreign substances Moisture content should be sufficient to secure proper compaction The fill material is placed in an approximately 6-inch layer that extends over the full width and length of the dam If the moisture content is deficient, water is sprinkled on the surface prior to placing additional fill If the moisture content of the material is excessive, it should not be used until it has dried to proper content Sufficient overfill is used to allow for settlement

Back-fill adjacent to the pipe spillway and stock-watering pipe must be free of rocks, or clumps Backfill is brought up approximately equal on each side of the pipe to prevent side movement Care should be taken to prevent the pipe from uplifting, while backfilling

Plate 35 (a, b) *Boulder pitching on earthen embankment given strength to the structure Cut spillways are cheap and quite effective to pass on the surplus water after the dam is full*



under the haunches. Heavy equipment should not be driven over the pipe until a minimum of 2 ft of compacted fill has been placed on top of it.

The topsoil saved during site preparation is placed as a topdressing on the surface of the earth fill and emergency spillway Exposed surfaces of the earth spillway, embankment, and borrow area that are not covered by the permanent pool should be fertilised, seeded, and mulched to provide a good vegetative cover.

The storage capacity of an earthen embankment can be approximately calculated from the following formula.

Storage (ha-m) = 0.4 D x A

where:

D = Maximum depth of water (m)
A = Area of water spread at waste weir

Farmponds

The primary function of a farmpond is to provide a water supply for irrigation, livestock, drinking, etc In building a good farm pond, watershed yield and soil suitability are of paramount importance Farm ponds can be impounding ponds or excavation ponds Impounding (embankment) ponds hold a large portion of the water above the original ground surface, and are usually built in areas where the land slopes are gentle to moderately steep and a dam can be constructed across a depression Usually, surface water fills the pond Excavated (dug-out) ponds have a large portion of the water stored below the original ground level They are usually constructed where the land slopes are relatively flat These ponds are not advisable when the quantity of water desired is not large The pond is filled by either surface runoff or groundwater seeping into the excavation Generally, the capacity of a farm pond is achieved by both excavation and impounding They are considered to be embankment ponds, if the depth of the water stored above the original ground surface at the embankment exceeds 3 ft Farm ponds are constructed to improve the availability of water for farm and non-farm operations (see Table 13 4)

Table 13.4 *Water requirements for farm users*

Type of use	*Average use in*	
	(gallons per day)	*(ha-m per year)*
Household, all purposes, per person	50-100	0 01
Dry cow	9-18	0 002 to
Milk cow, 450 kg(1000 lb)	18-40	0 004
Horse or mule	8-12	0 0014
Chickens per 100 head	6-9	0 001
Swine per 45 kg(100 lb)	1-1 5	0 0002
Sheep per 45 kg(100 lb)	1-1 5	0 0002
Orchard sparing, per year of tree age per application	1	
Irrigation (humid regions) per season		0 3-0 45
Irrigation (arid regions) per season		0 3-1 5

The size of the drainage is very crucial in construction of farm ponds The contributing drainage area should be large enough to maintain sufficient water in the pond If the drainage area is too large, then the spillway to be constructed will be costly and silt deposition will be high. The size of the drainage area may be changed by diverting the desired amount of water into or out of the pond drainage area by the use of waterways or diversion channels. A practical solution could be achieved by locating the pond beside a waterway at such a level that when the pond is not full, water from the waterway will flow into the pond, and when the pond is full, the majority of water enters the pond but will flow down the waterway It is advisable to select entire drainage area covered by permanent grass or vegetation otherwise the erosion from the drainage area will contribute silt and sediment to the pond, reducing its capacity and life If sloping land in the drainage area has to be cultivated then practices which will reduce the erosion to a minimum should be used In certain cases, if the soil erosion from drainage area is expected, a sediment basin could be constructed above the pond to collect the debris Pollution of the pond water should be avoided as far as possible Diversions can be used to keep undesirable drainage from entering the pond It is desirable to locate the pond in such a way that the drainage from the whole of drainage area enters into the pond If availability of the runoff water cannot be assured, it may be desirable to limit the size of the pond to be compatible with runoff from the owners' land The farm pond may be constructed on private land, community-owned land, government (revenue/forest) land

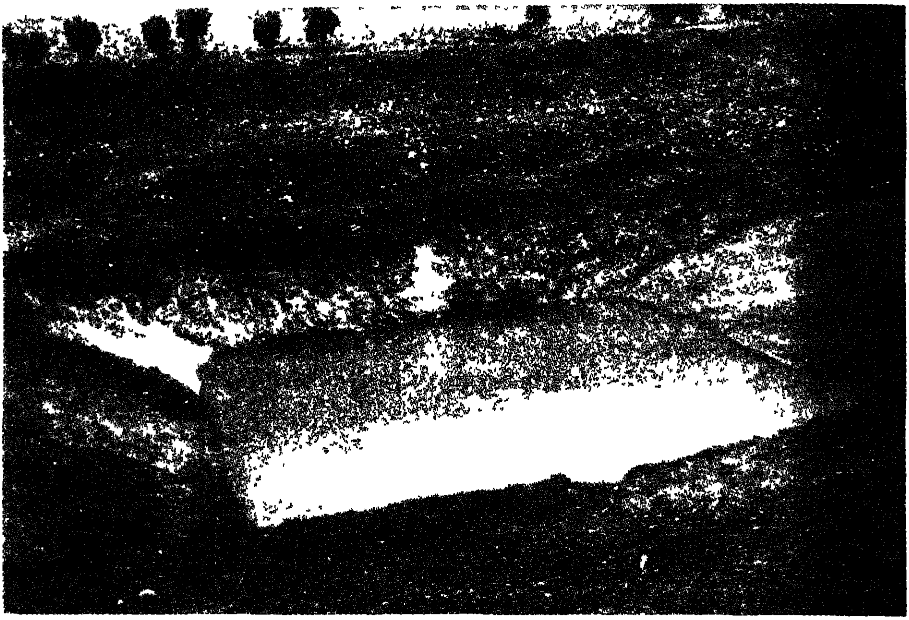
The topography of the land should be such that a pond of the desired capacity can be constructed at a reasonable cost Ideally, the pond should be located where the largest storage volume can be obtained with the least amount of earth moving This can be achieved by constructing farm pond across a narrow drainage way with backwater over a large area Livestock water ponds should be located close to grazing areas If the pond is to be used as a source of water for irrigation, it should be preferably located at a higher elevation The success of a farm pond is dependent on the ability of the soil in the reservoir area to hold water and provide a stable embankment (Plate 36)

The profile of materials present in the foundation area must be determined and in areas where the geology is well known, fewer courses are required A dam built on pervious material must be constructed with care that it extends through the material into some impervious layer The borrow area should be located as close the dam site as possible to reduce construction cost The proportion of the material advised is less than 20% gravel, 20-50% sand, less than 30% silt, and 15-25% clay The water storage area should be as impermeable as possible. Elimination of shallow water along the edges of the pond during the construction is accomplished by filling low areas with earth so that water will not be impounded on them

Graphs of surface area and storage volume versus elevation can be prepared from topographic maps. The storage versus elevation curve can be prepared by starting at the bottom of the farm pond where volume is zero Proceeding on a higher contour line, the whole curve can be established Farm pond should have adequate capacity to provide water for both use and natural loss Following should be considered while designing farmpond

(a) *Sediment* The runoff from the watershed contain sediment and they would deposit and accumulate in the reservoir over a period of time Space must be provided to receive the sediment deposit otherwise the reservoir will have inadequate capacity before reaching

Plate 36 *Excavated (dug-out) ponds have a large portion of the water stored below the original ground level They should be constructed where the land slopes are relatively flat*



the end of its design life An estimation of the volume required in the reservoir for sediment storage may be obtained from the following formula·

$$V = \frac{ST}{1500}$$

where

V = Volume required for sediment storage (acre ft)
S = Amount of soil loss from the watershed each year (tons)
T = Expected design life of the pond (years)
1500 = Bulk density of the sediment (tons/acre ft)

(b) *Reserve pool* Certain volume has to be kept for reserve pool which will prevent the pond from drying out, cracking and water is always available for *nistar* purposes The reserve pool depth depends upon the intended use of the farm pond It represents the minimum depth of the pool and should always exceed 3 ft to avoid weed problems The volume of the reserve pool can be estimated from the volume versus elevation curve

(c) *Evaporation·* The water loss from evaporation from the surface of the farmpond may exceed the amount replaced by the rainfall The evaporation loss can be calculated from the evaporation from the glass A-pans and multiplying it by 0 7

(d) *Seepage* Seepage rates of 1 inch per month for good construction and 2 inches per month for fair construction (or permeable soils) may be used Evaporation and seepage losses depend upon the surface area of pond, which itself varies through the year The area of the normal pool is the surface area of the pond when it is full The volume of water loss is the product of the average area and the depth of loss

(e) *Consumptive use.* Volume of water used for day-to-day consumption varies with the activity.

(f) *Detention storage* This usually is the volume contained between the principal spillway and emergency spillway elevations The runoff water from very heavy rains can be stored temporarily in detention storage and is slowly drained through the principal spillway protecting emergency spillway from damage

Size of the drainage area is a crucial step for construction of farm ponds It depends upon the amount of runoff especially when rainfall is limited. Land slope, soil infiltration, vegetative cover, surface storage, amount, intensity and duration of rainfall determine the runoff with geographical and seasonal variations

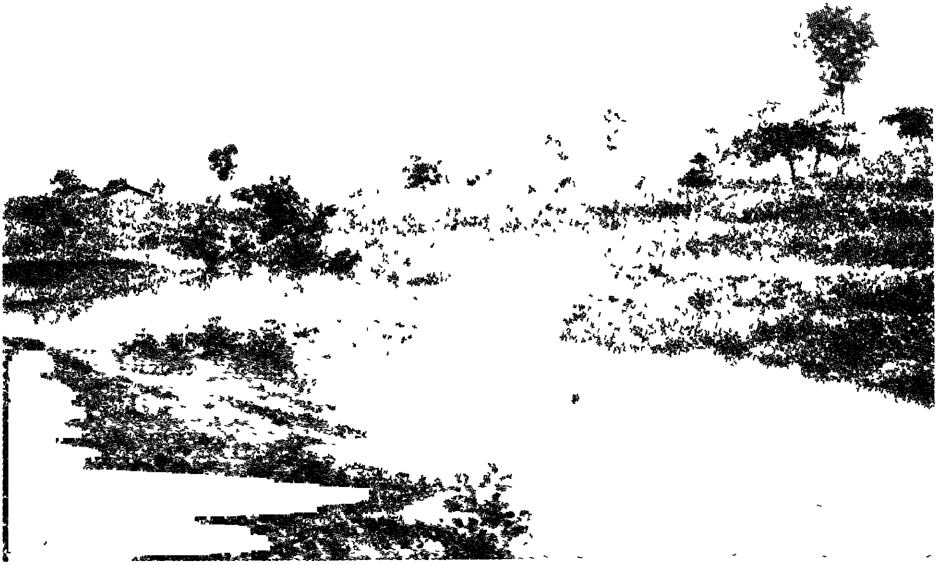
Excavated pond may be constructed in almost any shape. A rectangular pond is usually the most convenient and most commonly constructed Side slopes of 2·1 are commonly used If the pond is located on sloping land, excavated material may be used in an embankment around the lower portion of the pond to increase its capacity The seepage may be reduced to permissible limits by reducing the permeability of the soil The pond area should also be cleared of fallen trees, shrubs, stumps, roots and other debris Holes and crevices should be filled with compacted material prior to the treatment Pond areas with a high proportion of coarse grained material can be made impervious by compaction It is not a very costly procedure The soil is loosened to around 10 inches and all boulders, debris, etc , removed The loosened soil is moistened and rolled in dense, tight layer Generally, the thickness of the compacted seal should be kept at around 8 inches for impoundments upto 10 ft in depth. The thickness of the compacted seal should be increased by 1 inch for each foot of water beyond 10 ft Clay blankets, bentonite and chemical additives may also be used to reduce the seepage A permanent fence barricading the pond is desirable to prevent grazing cattle damaging the embankment and spillways A strip of permanent vegetative hedge, at least 30 ft wide, may be raised around the waterline.

Nalla bunding

Nalla bunding usually consists of constructing soil bunds of suitable dimensions across the *nallas* or gullies to hold the maximum runoff water (Plate 37) It creates flooding of up-stream area which requires surplussing arrangements at suitable intervals to drain water *Nalla* bunds should be avoided in isolation As tried out in Jhabua, integrated *nalla* bunding plan can be formulated and executed This helps in water harvesting, moisture control and groundwater recharge The number of such bunds primarily depends upon the slope of the gully or the *nalla* and the quantity of runoff It may not be advisable to construct *nalla* bunds on *nalla* with high gradient slope and where runoff of water flow is very high The *nallas* should be treated with drainage line treatment and gully control measures and *nallas* with high runoff flow should be treated with gabionic structures and boulder checks with masonary work to curtail the runoff (see Figure 13 5 a, b)

The temporary storage of runoff against these *nalla* bunds result in deposition of soil The impounding of water facilitates the percolation of water to the deeper layers of soil Without *nalla* bunds, excessive runoff may cause severe soil erosion and choking of natural drainage courses, lakes and reservoirs The *nalla* bund reduces the runoff and before the water flow gains momentum, it encounters the next bund down below in the *nalla* The basin at the upstream side of the bund gets enriched by the progressive silt

Plate 37 *Nalla bunding reduces the runoff and harvests the water They are preferable in arid and semi-arid regions with low rainfall and relatively permeable soils*



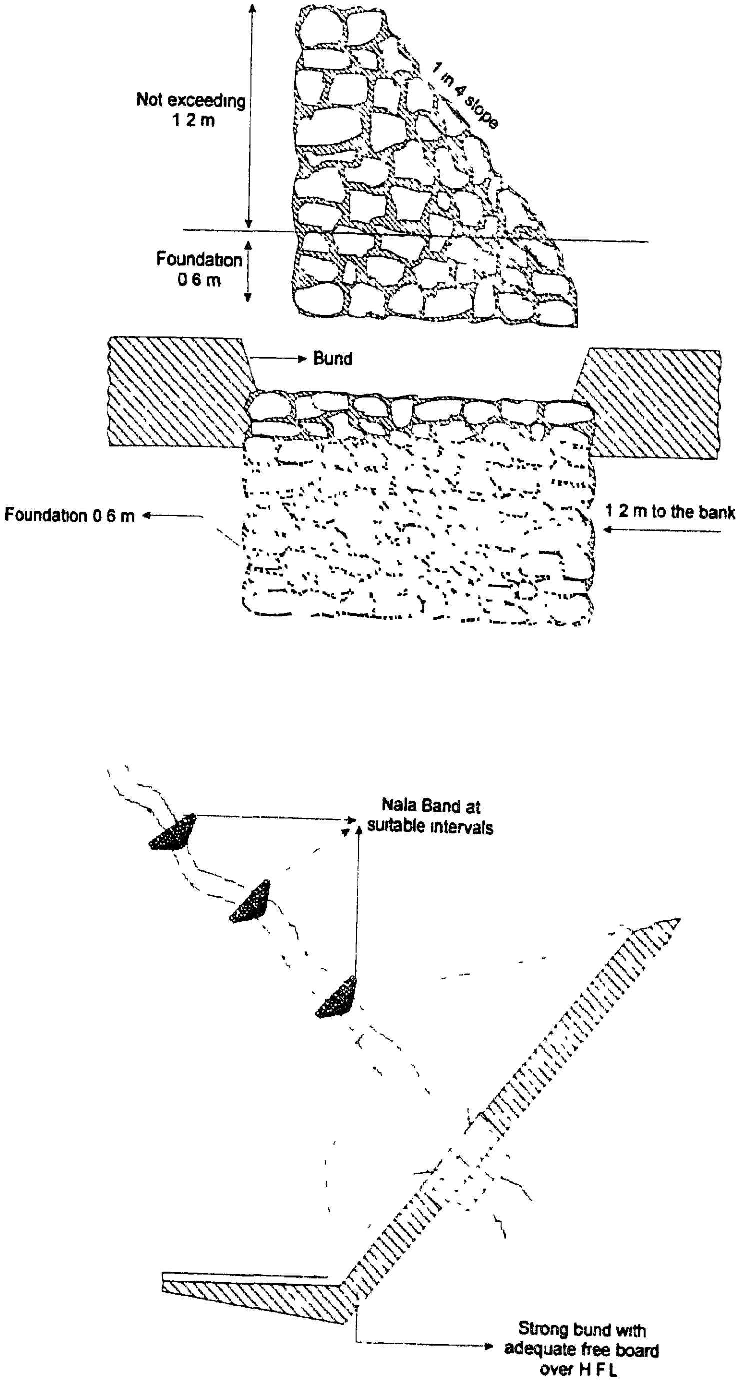
deposition. Construction of such *nalla* bunds facilitate reclamation of gullied lands and groundwater recharge

In semi-arid regions with low rainfall, and relatively permeable soils, bunds can be constructed from the top of the catchment, from ridge to valley, at regular intervals A detailed survey of the *nalla* at suitable locations with a suitable grid of 20 m to a maximum of 90 m should be conducted *Nalla* bunds should be located on the *nalla* in the survey plan and a detailed estimate should be prepared Location of the *nalla* checks on a *nalla* could easily be indicated by the villagers. After fixing different points such as FSL and HFL and cut outlets, the foundation could be laid down The puddle trench should be excavated and the core wall should be constructed Cut-out should then be excavated followed by digging and filling of embankment portion Earthen embankment is then constructed over the core wall and the stone pitching on the upstream side of the bund is carried out

Sand dams

It has been a common observation that dry sand river beds contain water at accessible depths Sand can store substantial quantities of water in the voids between the particles, specially when the voids are not filled by smaller particles Coarse sand of uniform size could store upto 45% of its volume and sand of grain sizes could hold upto 30% water The location of weir on suitable sites decide the volume of sand trapped behind the structure If the weirs are built progressively in phases with interval of about 1 m, coarse sand will be deposited behind the weir by the flooding water and the silt and clay is carried over the weir Further layers can be trapped by the addition of second stage to the weir The storage

Figure 13.5 (a, b) *Nalla bunding*



of water in this manner has been tried where the availability of clean water is scarce It is a very site specific structure The evaporation loss is negligible, once the water level has sunk to 1 m below the sand surface and the risk of waterborne diseases or contamination by animals is reduced Fresh water could also be supplied to the habitations.

Small weirs

Weirs are permanent structures constructed by concrete, brick or masonary Water flows over the top of the weir when the storage is full These structures can be more suitable than earth dams or *nalla* bunds when the gradient of the slope or the runoff velocity of water is high (Plate 38 a, b). In the following situations the weirs could be constructed.

- when the permanent flow of water is large enough to pass through a spillway,
- when the runoff velocity of water is exceptionally high on high rainfall days and when the gradient of the stream or *nalla* is steep,
- when the object is to raise the water level and in place of storage, diversion into a canal is preferred,
- when the object is to control gully formation, and
- when the object is to trap sediment

Following types of weirs are prevalent

- arch weir,
- slab-and-buttress weir,
- gravity weir,
- masonary used as shuttering for concrete weir,
- brickwork used as shuttering for concrete weir, and
- rock fill dam with concrete cover

Gravity weirs depend on their width for their stability For other structures, the back slope can be kept at 2 horizontal to 3 vertical The crest width of the structure depends on the wall height For the wall heights of weirs upto 1 m, 1-1 5 m and 1 5-2 m, the crest width would be 0 3 m, 0 4 m and 0 5 m respectively The weir structures can be constructed by concrete or masonary into wooden shuttering Brickwork can also be used to form outside layer as the shuttering Rock fill dam is another kind of gravity weir in which a pile of rocks and boulders give the stability and a concrete structure over it makes it water tight All the above mentioned structures need a large amount of material for construction (see Plate 39 a, b) Arch weir and slab-and-buttress weir curtail the requirement of material In arch weir, the pressure of the water is resisted by the buttresses at each end In the slab-and-buttress, the vertical slab is held up firmly by the buttress These can be constructed upto a height of about 1 m without outside technical assistance

Weirs require solid rock foundation in the full width of the stream channel All dirt, soil and debris should be cleared loose or cracked rock should be chipped off If the surface is smoothened by water flow, it can be roughened by chipping or between the foundation and the concrete cement and water may be brushed on the rock surface Mortar mix of six sand to one cement by volume is used along with brick masonary shuttering All joints should be filled with mortar Coarse stone aggregate and graded mixture of stones (2 mm to 50 mm) can be used in construction A suitable mix is 1 part cement by volume, 3 parts sand and 6 parts stone The quantities required per cubic metre of concrete are 0 15 m^3 cement, 0 5 m^3 sand, 1 m^3 stone and 70 litres of water Concrete on the structure should not

Plate 38 (a, b) *Gabion structures are semi-permanent structures for water harvesting Local modifications like concrete core wall gate, etc , should be encouraged*

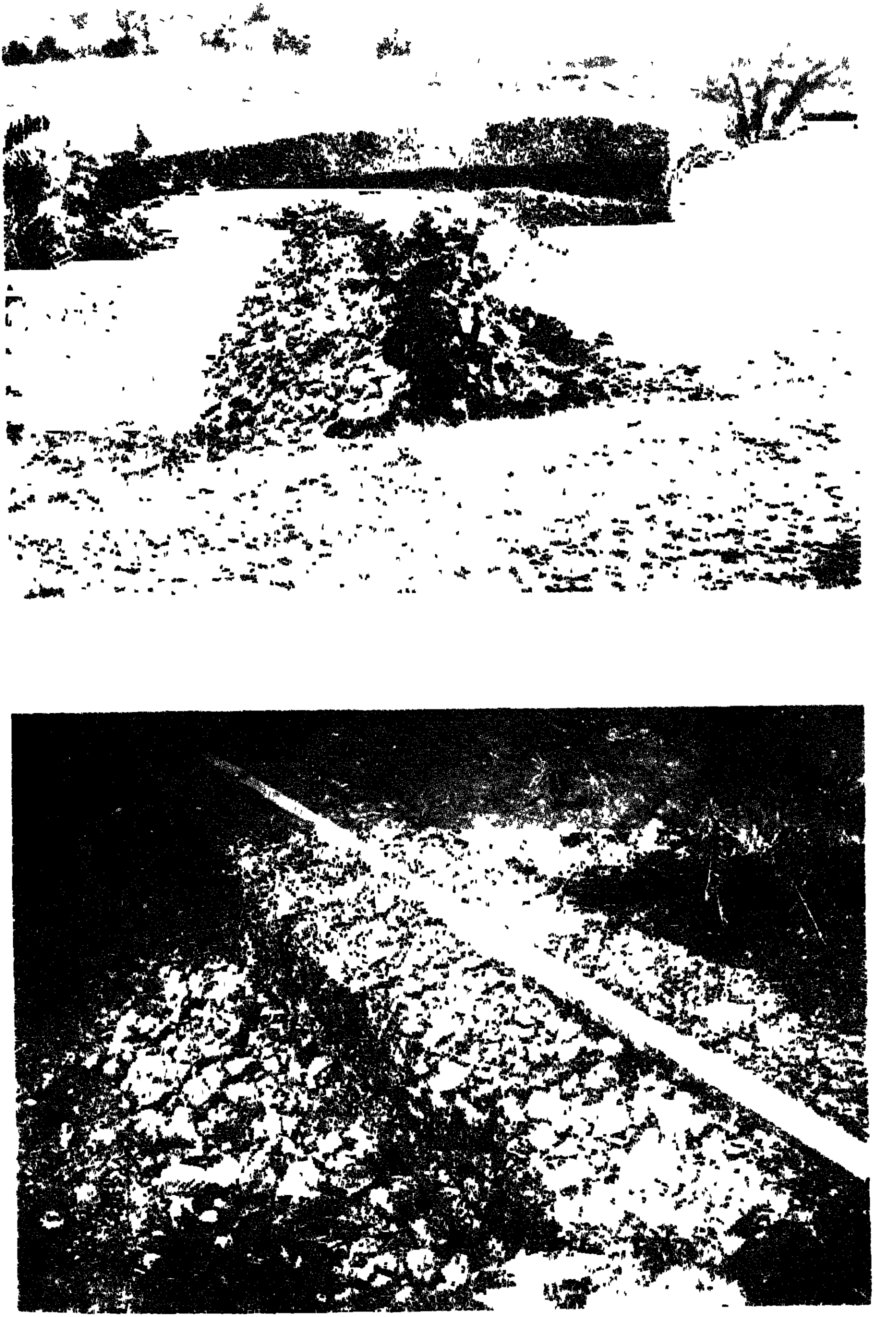
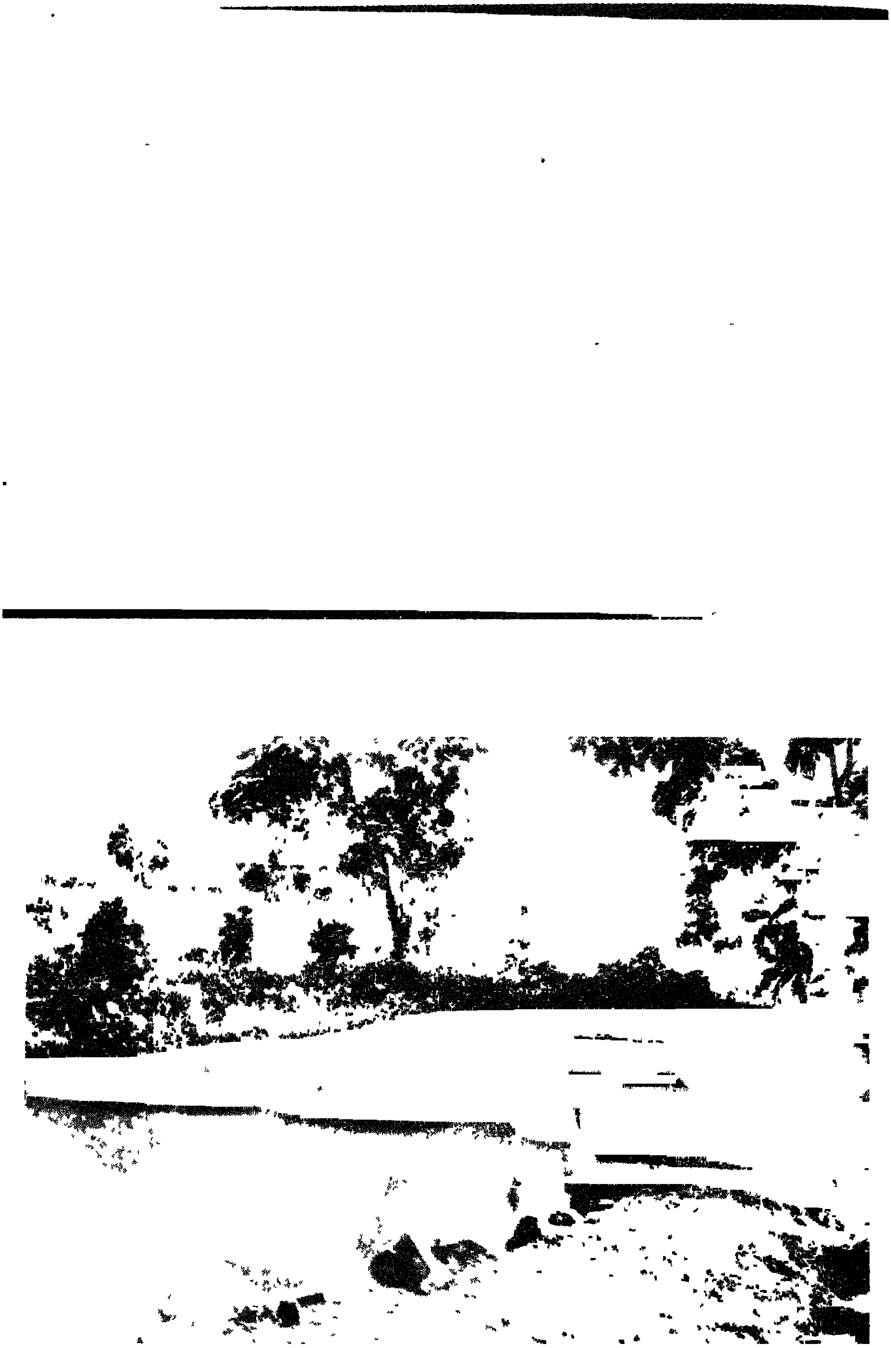


Plate 39 (a, b) *Permanent water harvesting structures should be constructed at appropriate place and where maximum benefits could be extracted from them*



be allowed to dry out and settle down too quickly, as it may cause cracking and loss of strength The structure should be cured for about 7-10 days. Vegetative barriers and diversion channels may be used along with the weirs to provide additional support to the structure

Off-stream storage

It may not be feasible in certain situations to construct storage structures on the stream In these circumstances, a storage structure or reservoir may be constructed which is filled by diverted water from the stream. Off-stream storage is costlier than on-stream structures, and they should be used for purposes like drinking water or domestic use in habitations. Though it is costlier, these reservoirs can be located at the most desired sites. They can be constructed in numerous sizes and shapes depending upon the slope of the ground, the kind of water supply and the use for the water The efficacy of a storage structure depends upon the storage/excavation ratio (proportion of storage capacity generated divided by the volume of the excavated earth) The S/E ratio is 1 when a hole is dug and water is stored into it A natural depression at the site may lead to a better S/E ratio If the soil dugout is used to form a surrounding bank around the waterbody, then the ratio will increase Gentle gradient terrain (with 1-5% slope) give better S/E ratios than flat grounds It is cheaper to use flood water to fill up the reservoir than the pumping Though in dry conditions, pumping may have to be used alongwith diversion of water from the stream In arid and semi-arid climatic conditions, evaporation may be decreased by increasing the depth and decreasing the surface area In India, the construction of tanks or *talaabs* can be adjudged as an indigenous version of off-stream storage reservoir These structures have advanced water control mechanisms and often have community-based management systems Often, these structures are multipurpose as the water body so created is used for irrigation, drinking water, domestic use, stock consumption, *nistar* use, fish production, *singhada* cultivation, etc

Rectangular tanks are most commonly built They provide good S/E ratio (1 5-3) on gentle slopes Catch drains pick up surface runoff or the diversion channels bring excess overflow water from the stream Surplus water in these tanks is safely spilled through spillways or waste weirs Ring tanks give better S/E ratio on flat or nearly flat terrain as compared to rectangular tanks The S/E ratio increases with size of the ring tank

Losses of water from storage structures

Losses of stored water from a storage structure is a nasty nuisance as it leads to wastage of water and damage to the structure The commonest cause of water loss is seepage and can sometimes be so serious that it may completely drain the reservoir or stored water The seepage may happen from leaking basin or dam wall and may lead to water-logging and salination In hot arid and semi-arid areas, the water loss from evaporation can be substantial

Seepage losses

The seepage losses may be of horrendous proportion due to the light texture of soil and permeable sub-strata The practical solution could be lining of the pond or reservoir Cost, availability of material, ease of application, acceptability by the community, durability, soil and sub-strata conditions and annual maintenance and repair costs may decide the choice of the lining material. Numerous materials have been tried and tested for lining, but almost all of them are quite costly So, the use of these lining materials in integrated watershed development programme essentially depends upon the fund availability.

Much of the information regarding sealing materials for ponds and reservoirs is found in USDA (1969). Excessive seepage losses in reservoirs are usually due to the selection of a site where the soils are too permeable to hold water. The need for water may be so important as to justify the selection of a permeable site In such cases, plans for reducing seepage losses by sealing should be part of the design.

(a) *Compaction* Pond areas containing a high percentage of coarse-grained material can be made relatively impervious by compaction alone if the material is well graded from small gravel or coarse sand to fine sand, silt and clay This method of sealing is the least expensive of those presented but its use is limited to the soil conditions described. The soil should be scarified to a depth of 20-25 cm and all rocks and tree roots should be removed The loosened soil should be rolled, under optimum moisture conditions into a dense, tight layer.

The thickness of the compacted seal should not be less than 8 inches for impoundments upto 10 ft in depth Since seepage losses vary directly with the depth of water impounded, the thickness of the compacted seal should be increased by 1 inch for each foot of water over 10 ft. This will require compacting the soil in two or more layers, not exceeding 8 inches in thickness, over that portion of the pond where the water depth exceeds 10 ft

(b) *Clay blankets*· Pond areas containing high percentage of coarse-grained soils but lacking sufficient amount of clay to prevent high seepage losses by compaction alone can be sealed by blanketing. The blanket should cover the entire area over which water is to be impounded. It should consist of material containing a wide range of particle sizes varying from small gravel or coarse sand to fine sand and clay in the desired proportions Such material should contain approximately 20% by weight of clay particles The thickness of the blanket will depend on the depth of water to be impounded The minimum thickness should be 12 inches for all depths up to 10 ft The minimum should be increased by 2 inches for each foot of water over 10 ft

(c) *Bentonite*: Seepage losses in well-graded coarse-grained soils may be reduced by the addition of bentonite, a fine-textured colloidal clay that will absorb several times its own weight At complete saturation, it will swell from 8 to 15 times its original volume When bentonite is mixed in the correct proportions with the coarse-grained material and the mixture is thoroughly compacted and saturated, the particles will fill the pores in the material and make it nearly impervious Bentonite is not recommended where a wide fluctuation in water level is expected, as it cracks when the reservoir dries If the area is too wet, sealing operations should be postponed until moisture conditions are satisfactory It is thoroughly mixed with the soil to a depth of at least 6 inches with a rotary cultivator, disk, or similar equipment The area should then be compacted

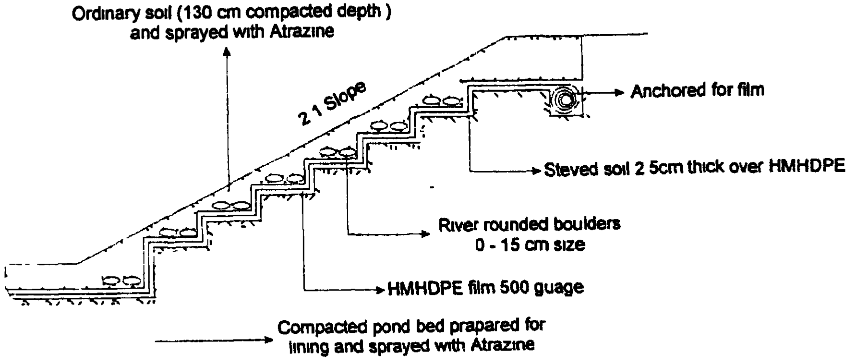
(d) *Chemical additives* Excessive seepage losses often occur in fine-grained clay soils because the clay particles form a honeycomb structure Such soils have a relatively high permeability rate The application of small amounts of certain chemicals to these aggregates may result in collapse of the open structure and rearrangement of the clay particles The chemicals used are called dispersing agents For chemical treatment to be effective soils in the pond area should contain more than 50% of fine grained material (silt and clay finer than 0.075 mm diameter) and at least 15% of clay finer than 0.002 mm diameter. The soil should contain less than 0.5% soluble salt (based on dry soil weight). Chemical treatment is not effective in coarse-grained soils.

While there are many soluble salts that meet the requirement of a dispersing agent, sodium polyphosphates are most commonly used Tetrasodium pyrophosphate (TSPP) and sodium tripolyphosphate (STPP) are most effective. A laboratory analysis of the soil in the pond area is essential to determine which of these dispersing agents will be most effective and the rate of application. The dispersing agent is mixed with the surface soil and compacted to form a blanket For depths of water up to 8 ft, the blanket thickness should be at least 6 inches. For depths greater than 8 ft the blanket should be 12 inches thick and treated in two 6-inches fill.

The soil moisture level in the area to be treated should be near optimum for compaction to a depth of 12 inches. If the soil is too wet, treatment should be postponed. If the soil is too dry, water should be added by sprinkling. The dispersing agent should be applied uniformly over the pond area Each chemically treated layer should be thoroughly compacted. The treated blanket should be protected from puncture by livestock trampling

(e) *Flexible membranes* Another method of reducing excessive seepage losses is the use of flexible membranes of polyethylene, vinyl or butyl rubber (see Figure 13.6). Thin films of these materials are structurally weak but if kept intact, they are almost completely watertight. Polyethylene films are less expensive and have better aging properties than vinyl. Vinyl is more resistant to impact damage and is readily seamed and patched with a

Figure 13.6 *Lining of farm pond using HMHDPE film*


Ordinary soil (130 cm compacted depth) and sprayed with Atrazine
2:1 slope
Anchored for film
Sieved soil 2 5cm thick over HMHDPE
River rounded boulders 0 - 15 cm size
HMHDPE film 500 guage
Compacted pond bed prapared for lining and sprayed with Atrazine

solvent cement. Polyethylene can be joined or patched only by heat sealing. Butyl rubber can be joined or patched with a special cement The area to be lined should be drained and allowed to dry until the surface is firm and will support the men and equipment that must travel over it during installation of the lining. Certain plants penetrate vinyl and polyethylene film. For this reason, it is desirable to sterilise the surface with chemicals Sterilisation is not required where butyl rubber membranes are used. The top edges of the lining should be anchored in a trench excavated completely around the lining. The trench should be 8-10 inches deep and about 12 inches wide. The lining should then be anchored by burying 8-12 inches of the lining in the anchor trench and securing it with compacted backfill The linings are usually laid in section or stips with a 6 inches overlap for seaming. Vinyl and butyl rubber linings should be laid smooth but in a loose state Polyethylene should have upto 10% slack

These thin films must be protected from mechanical damage if they are to be serviceable All polyethylene and vinyl rubber membranes should have a cover of earth or earth and gravel not less than 6 inches thick. Butyl rubber membranes need to be covered only in areas subject to travel by livestock, where a minimum cover of 9 inches should be used The materials used should be free of large clods, sharp rocks, sticks, and other objects that would puncture the lining.

(f) *Soil-cement/cement-concrete/asphaltic cement lining:* Well graded sandy soils mixed with cement in the ratio of about 10 1 by volume and applied in the thickness of 7 5-15 cm reduce the seepage rates from reservoirs considerably. Proper watering and airing cement-concrete lining is the most effective but is very high capital intensive Cement concrete of 1 3 6 mixture is applied to the thickness of 3-5 cm on the bed and sides of the pond after compaction The maintenance cost of such lining is minimum and the life is long Another lining mechanism consisting of use of mixture of sand and gravel bound together with asphaltic cement The asphaltic cement lining also gives zero seepage results But it is very costly, absorbs heat and encourages the growth of underlying vegetation, which may pierce the lining Where stone slabs or boulders are easily available as in the case of western India, these slabs can be laid in cement mortar (1 3) directly on the bed and sides of the storage structures Bricks may also be used but they are costly and need 1 cm plaster of rich cement mortar

Evaporation losses

The losses from evaporation could be substantial in arid and semi-arid regions due to high temperature, low rainfall, low relative humidity and high wind speed A lot of research has been taking place the world over to ascertain a mechanism which can decrease the evaporation losses from the storage sites Several anti-evaporants such as floating plastic membranes/foamed rubber sheets/polystrene sheet, foamed wax blocks, asphalt-concrete blocks, plant residues like straw, saw dust, wood bark or oil residues, silicon, gum mixtures, etc., for the control of evaporation from the water bodies are under consideration and evaluation All these measures are very costly and are not very efficient Still, the search for economical, efficient, practical and durable anti-evaporant is still going on Evaporation losses can be reduced by modification in structure design and management Reduction of surface area of the water body *vis-a-vis* depth of volume of the water is most commonly and universally practised mechanism of structural design. The decrease in surface area reduces the size of the evaporating surface and avoid heating effect. Compartmentalised reservoirs could be yet another option. The reservoir, in place of constructing a large body with thin water layer in it, can be constructed in numerous compartments Some of these compartments are more filled than others.

Water harvesting for trees and shrubs

Trees and shrubs are an important aspect of the ecosystem Biotic pressure in diverse forms are creating degraded forests and depletion of natural stocks of trees and shrubs The usual techniques for afforestation are seldom appropriate in arid and semi-arid regions. Thus, unreliability of the rainfall, poor and shallow edaphic conditions and difficulty in protecting the young plants are major factors making the process of plantation very unreliable. Wherever total exclusion of stock by stalled feeding and social fencing has been possible, the protection of the grass can be extended to trees and shrubs

Several methods have been instituted and developed to increase the amount of water available for tree production in low rainfall areas, using the rainfall multiplier approach. Micro-catchment *(negarin)* are developed as runoff farming in certain areas. It consists of basin with cross-section area of 250 m^2 as the catchment area surrounded by a low earth bank At the lowest point within the basin a deeper basin of 3 5x3 5 m is excavated, in which one seedling is planted Another variation of micro-basin has been effectively tried in Kenya In this, planting holes 60x60x30 cm deep are dug with a collecting drain of 3-5 m long and at the spacing of 5x5 m Collecting drains form two arms of a V, leading runoff into the planting hole During heavy runoff surplus water spills out at the end of the collecting drains As many as 400 trees per hectare can be planted in this method Other variation of this method includes small lunettes and lines of small semi-circles

Wherever water is retained by some kind of contour furrows, trees or shrubs can be planted in lines Most commonly used practice is water harvesting by construction of micro-basins These are small structures with a shape of half or full moon excavated creating a small basin for planting a tree Micro-basins can have various sizes and shapes These are kept small in moist areas and large in dry agro-climatic zones These small but effective structures or micro-basins harvest water from a large area (6-10 sq m) on gentle slopes in dry areas These structures protect soil erosion and support soil formation. Ideally micro-basins should be carefully lined out on the slope with runoff control structures and proper spacing

In Jhabua, which falls in semi-arid and sub-humid agro-climatic zone, cheaper versions of water harvesting for trees and shrubs have been used Most common and successful method is planting of sapling in the centre (or in the deepest portion) of staggered or continuous contour trenches The trenches act as collection ditches for these saplings Survival of the sapling is found much better than normal planting Planting close to storage site with slight seepage from basin wall has also shown promising results. Similarly, planting in *thale* or circular excavated pit of around 2-2 5 m diameter has given better results, more so in upper recharge zone The *thale* are provided with small miniscule banks and shouldering along the surface In cases of dryland horticultural species, planting is supported by putting down porous earthen pots in the sapling pit itself Water is filled every second to fifth day. Porosity in the pot *(matka)* help to retain moisture in the pit for few days. Numerous indigenous systems of water harvesting for plants and shrubs are practised in various parts of India Those indigenous techniques should be included in water harvesting and moisture control plan for trees and shrubs in watershed areas, especially in arid and semi-arid climatic regions

14

Groundwater Management in Watershed

Groundwater is a precious renewable resource which gets replenishment from the precipitation Total water resources of the world are estimated at 1 37×10^8 million ha-m. Of these, about 97 2% is salt water, mainly in oceans, and only 2 8% is available as fresh water And, out of this 2 8%, about 2 2% is available as surface water (2 1% is fresh water in glaciers and icecaps, 0 1% is available in lakes and reservoirs, 0.0001% in streams) and 0 6% is available as groundwater Only 50% of groundwater resource is economically extracted with available technology Presently, 1 36×10^4 million ha-m fresh water in reservoirs and 41.1×10^4 million ha-m groundwater is theoretically available to provide usable water for drinking, domestic use, irrigation, etc , to mankind Groundwater is the largest source of fresh water excluding the polar icecaps and glaciers The amount of groundwater within 800 m from the ground surface is over 30 times the amount in all fresh water lakes and reservoirs, and about 3000 times the amount in stream channels, at any one time

At present, nearly one-fifth of all the water used in the world is obtained from groundwater resources Agriculture is the greatest user of water, accounting for 80% of consumption In India, 40% of total irrigated land (60 m ma) is being irrigated by groundwater It has been estimated by Dr K L Rao that the total annual rainfall over the entire country is of the order of 370 million ha-m. One-third of this is lost in evaporation, 167 million ha-m goes as runoff and the rest of 80 million ha-m goes as sub-soil water Out of 80 million ha-m 37 million ha-m is the contribution of rainfall to groundwater The average annual groundwater recharge from rainfall and seepage from reservoirs and canals is of the order of 67 million ha-m, of which 40% (i e , 27 million ha-m) is economically extractable. The present utilisation of groundwater is roughly 13 million ha-m.

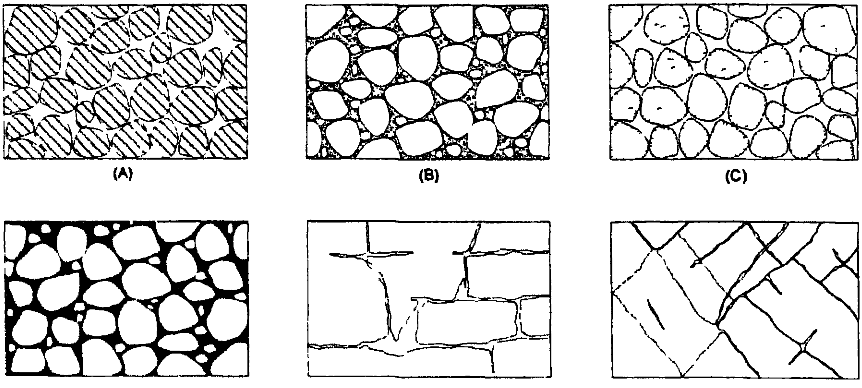
Groundwater is available in the voids formed in the interspaces between the individual soil particles The void space in the soil particles is represented by a term *porosity* which is defined as the ratio of void volume to the bulk volume of the material Porosity depends on the size, shape and arrangement of individual particles and their compaction Porosity may vary from zero to about 50% For finer particles, porosity is higher *Hydraulic conductivity* is the second most important factor which governs the groundwater availability. It is the measure of the ease with which water can flow. It is defined as the discharge through a unit cross-sectional area of the aquifer under a unit hydraulic gradient at the prevailing temperature of the water. For coarse-grained particles, the hydraulic conductivity is higher.

The two sources of water, viz., surface water and groundwater are interdependent. For example, many surface streams receive a major portion of their flow from groundwater. Also water from surface streams is the main source of recharge for the groundwater. The two sources of water are definitely interrelated, and use of one may affect the water available from the other Both surface water and groundwater should be considered together in plans for water resource development in integrated watershed management

Occurrence of groundwater

Immediately below the ground surface, the soil pores contain both water and air in varying amounts (see Figure 14.1) After a rain, infiltrated water moves downward through this *zone of aeration (vadose zone)* Some water is dispersed through the soil and held by capillary force in the smaller pores or by molecular attraction around the soil particles Water in these upper layers of the zone of aeration is known as *soil moisture* When the retention capacity of the soil in the zone of aeration is satisfied, water moves downward into regions

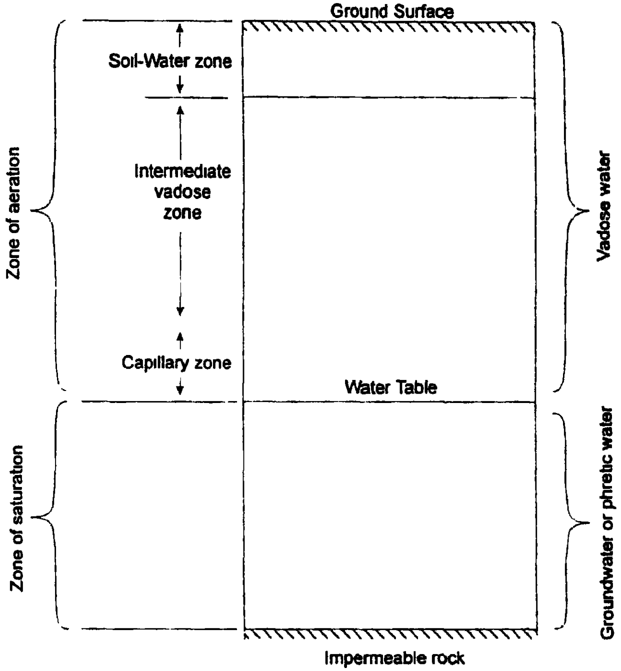
Figure 14.1 *Example of rock interstices and the relation of rock texture to prospority*



(a) Well - sorted sedimentary deposit having high porosity
(b) Poorly sorted sedimentary deposit having low porosity
(c) Well-sorted sedimentary deposit consisting of pebbles that are themselves porous so that the deposit as a whole has a very high porosity (d) Well - sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstics
(e) Rock rendered porous by solution (f) Rock rendered porous by fracturing (after Meinzer[11])

where the pores of the soil or rock are completely filled with water. The water in this *zone of saturation* is called *groundwater*, and its replenishment by water moving downward is termed as *recharge.* Almost all groundwater can be thought of as a part of hydrologic cycle, including surface and meteoric water Relatively, minor amounts of groundwater may enter this cycle from other origins (see Figure 14.2).

Figure 14.2 *Divisions of sub-surface water*



Water table

The boundary between the vadose zone and zone of saturation is termed as *water table.* Its location is determined by the elevation to which water rises in unpumped well just penetrating the top of the zone of saturation The water table is commonly higher under hills than under valleys and the contour map of the water table in an area may look like the topographical contour map. The water table is the surface of a water body that is commonly adjusting itself towards an equilibrium condition If there is no recharge to or outflow from the groundwater in a basin, the water table eventually becomes horizontal Some areas receive more rain than others and some portions of the basin have more permeable soil. So when intermittent recharge occurs, mounds and ridges form in the water table under the areas of greatest recharge. Subsequent recharge creates additional mounds, perhaps at other sites in the basin Influence of lakes, streams and wells also disturb the water table and a complex system of a water table constantly adjusting towards equilibrium evolves. Due to the low rates in most groundwater systems, this equilibrium is rarely attained, before additional disturbances occur. When water occurs in cracks, fissures and caverns, adjustments in water table are more quick Water levels may vary considerably between entirely separate openings in the same formation. Wells driven into such formations will yield little water unless they intersect on the caverns or fissures

Source of groundwater

The main source of groundwater is precipitation, which may penetrate the soil directly to the groundwater or may enter surface streams and percolate from these channels to the groundwater. Interception, depression storage and soil moisture must be satisfied before any large amount of water percolates to the groundwater. This low priority limits the rate at which groundwater may be exploited. Generally, only prolonged periods of heavy precipitation can supply large quantities of water for groundwater recharge, which itself is an intermittent and irregular process Geologic conditions determine the path by which water from precipitation reaches the zone of saturation If the water table is in the proximity of surface, there may be considerable percolation through the soil Relatively impermeable layers above the water table may prevent such direct percolation The rate of percolation from influent stream is limited by the extent and character of the underlying material Other sources of groundwater include water from deep in the earth that is carried upward in intrusive rocks and water trapped in sedimentary rocks during their formation The quantities of such waters are small

Rock properties affecting groundwater

(a) *Aquifers* Groundwater occurs in many types of geological formation called *aquifers* An aquifer may be defined as geologic formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs This implies an ability to store and to transmit water Synonyms frequently used for aquifer are groundwater reservoir and water bearing formation The aquifers may generally be overlain or underlain by a confining bed, which is a relatively impermeable material There are various kinds of confining beds

(i) *Aquiclude* A saturated but relatively impermeable material that does not yield appreciable quantity of water to wells (e g , clay)

(ii) *Aquifuge* A relatively impermeable formation neither containing nor transmitting water (e g , solid granite)

(iii) *Aquitard*: A saturated but poorly permeable stratum that impedes groundwater movement and does not yield water freely to wells but may transmit appreciable water to or from adjacent aquifers (e g , sandy clay)

(b) *Porosity* Those portions of rocks or soils which are not occupied by mineral matter may be occupied by groundwater Such spaces are termed as voids, pores or interstices Such interstices serve as water conduits and are characterised by their size, shape, irregularity and distribution Original or primary interstices are created by geologic processes governing the origin of the geological formation (e.g , seen in sedimentary and igneous rocks) Secondary interstices develop after the formation of rock (e g , joints, fractures, solution openings and openings formed by plants and animals). Interstices may be classified as capillary, super-capillary and sub-capillary. based on their size Capillary interstices are sufficiently small and surface tension forces hold water within them Supercapillary interstices are larger than capillary ones and sub-capillary interstices are so small that water is held primarily by adhesive forces In terms of groundwater, granular sedimentary deposits are of major importance. Representative porosity values for various geologic materials are listed in Table 14 1. Generally, porosity decreases with depth of burial

Table 14.1 *Representative values of porosity*

Material	*Porosity per cent*	*Material*	*Porosity per cent*
Gravel (coarse)	28	Duke sand	45
Gravel (medium)	32	Schist	38
Gravel (fine)	34	Siltstone	35
Sand (coarse)	39	Claystone	43
Sand (medium)	39	Shale	6
Sand (fine)	43	Till (mostly silt)	34
Silt	46	Till (mostly sand)	31
Clay	42	Basalt	17
Sandstone	33	Gabbro (weathered)	43
Limestone	30	Granite (weathered)	45
Dolomite	26		

Adopted from *Moris and Johnson*

(c) *Specific surface* The water retentive property of a soil or rock is markedly influenced by its surface area This area depends on particle size and shape and on type of clay minerals present Specific surface refers to the area per unit weight of the material, expressed as m^2/gm

Vertical distribution of groundwater

The zone of aeration consists of interstices occupied partially by water and partially by air In the zone of saturation all interstices are filled with water under hydrostatic pressure. Mostly, a single zone of aeration overlies a single zone of saturation and extends upward to the ground surface The saturated zone extends from the upper surface of saturation down to underlying impermeable rock Water occurring in the zone of saturation is commonly referred to as groundwater

(a) *Zone of aeration* Soilwater zone extends from the ground surface down through the major root zone and its thickness varies with soil type and vegetation. The amount of water present in the soil water depends primarily on the recent exposure of the soil to moisture Hygroscopic, capillary and gravitational water may be available *Intermediate vadose zone* extends from the lower edge of the soil water zone to the upper limit of the capillary zone The thickness may vary from zero to 100 m The zone primarily serves as a region connecting the zone near ground surface with that near the water table through which water moving vertically downwards must pass *The capillary zone* extends from the water table upto the limit of capillary rise of water The thickness of the capillary zone vary inversely with the pore size of soil or rock Just above the water table almost all pores contain capillary water, only the smaller connected pores contain water and still higher, only the few smallest connected pores contain water lifted above the water table.

Water holding capacity of plants is defined by the available water, which is the range of plant available water, the moist end being the field capacity and the dry end the wilting point. *Field capacity* can be defined as the amount of water held in a soil water and after subsequent drainage has become negligibly small. The *wilting point* defines the water content of soil when plants growing in that soil are reduced to a permanent wilted condition. This varies with soil type and volume, plant type and age.

(b) *Zone of saturation*: In the zone of saturation, groundwater fills all the interstices. The porosity provides a direct measure of the water contained per unit volume. A certain portion of water can be extracted from sub-surface strata by drainage or by pumping of a well. Molecular and surface tension forces hold the remaining water in place. Fine-grained materials yield little water, whereas coarse-grained materials permit a substantial release of water.

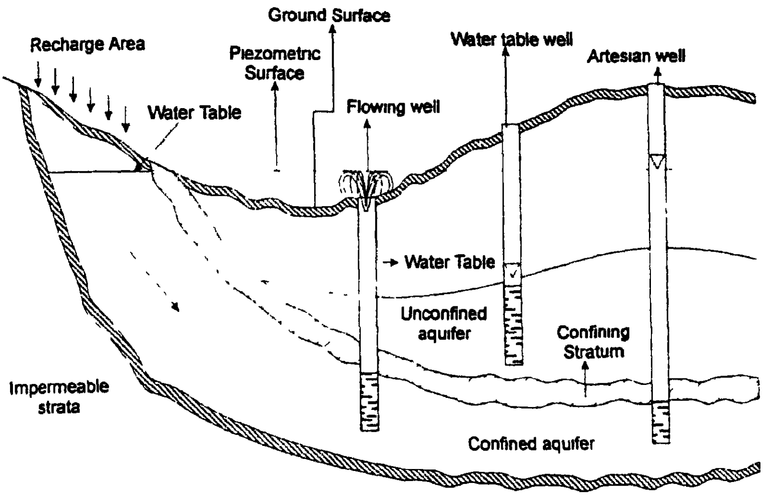
Aquifers

Aquifers have ability to store water in the rock pores Porosity may be derived from intergranular spaces or from fractures Most aquifers are of large areal extent and may be visualised as underground storage reservoirs. Water enters in an underground reservoir from natural or artificial recharge. Generally, the annual volume of water removed or replaced from these underground reservoirs represent only a small fraction of the total storage capacity Aquifers are classified as unconfined or confined, depending on the presence or absence of a water table, while a leaky aquifer represents a combination of the two types.

(a) *Unconfined aquifers*· These are the ones in which a water table varies in undulating form and in slope, depending on areas of recharge and discharge, pumping from wells and permeability. Rise and fall in the water table corresponds to changes in the volume of water in storage within an aquifer. They are often the uppermost resource in a system of aquifers underlying an area They are often the most accessible water resource but they are also often the most vulnerable to contamination The specific yield of an unconfined aquifer is the fractional volume of water that will drain freely by gravity from a unit volume of the aquifer Specific yield will always be less than porosity as some water will be retained in the aquifer by molecular or capillary forces The specific yield of fine-grained materials is much less than that of coarse materials The most economically important aquifers are deposits of sand and gravel, which have a fairly high specific yield Contour maps and profiles of the water table can be prepared from elevation of water in wells that tap the aquifer to determine the quantities of water available and their distribution and movement A special case of an unconfined aquifer involves perched waterbodies which are separated from the main groundwater by relatively impermeable stratum of small areal extent and by the zone of aeration above the main body of groundwater Wells tapping these sources yield only temporary or small quantities of water

(b) *Confined aquifers (artesian)* Also called *pressure aquifers*, occur where groundwater is confined under pressure greater than atmospheric pressure by overlying relatively impermeable strata In a well penetrating such an aquifer the water level will rise above the bottom of the confining bed Water enters a confined aquifer in an area where the confining bed rises to the surface where the confining bed ends underground, the aquifer becomes unconfined A region supplying water to a confined aquifer is known as a *recharge area*, water may also enter by leakage through a confining bed Rise and fall of water in wells penetrating confined aquifers result primarily from changes in pressure rather than changes in storage volumes. The economic importance of confined aquifers lie in the fact that they transmit water to substantial distances and deliver it above the level of the aquifer, thus minimising pumping costs (see Figure 14.3).

Figure 14.3 *Schematic cross-section illustrating unconfined and confined aquifers*



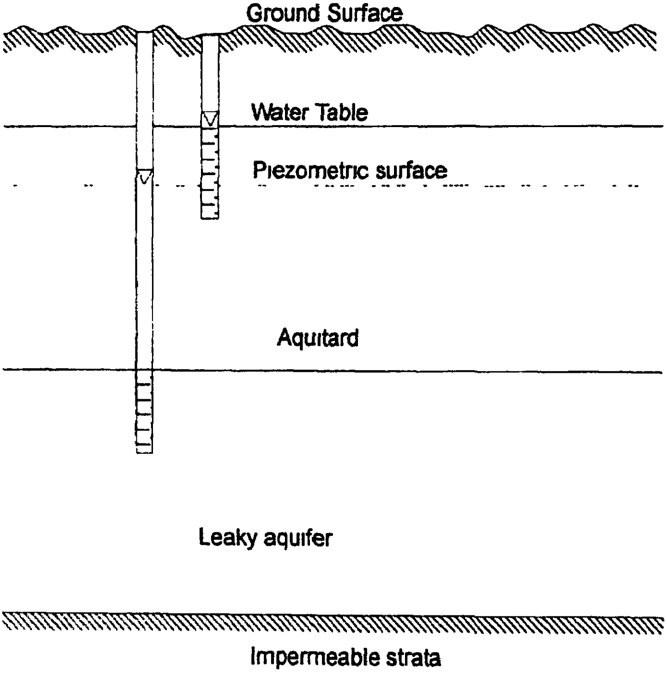
(c) *Leaky aquifers.* Aquifers that are completely unconfined or confined occur less frequently than do leaky or semi-confined aquifers. They are quite common in alluvial valley and plains where a permeable stratum is overlain or underlain by a semi-pervious aquitard or semi-confining layer. Pumping from a well in a leaky aquifer removes water either by horizontal flow within the aquifer or by vertical flow through the aquitard into the aquifer or both.

(d) *Idealised aquifers·* For practical purposes, aquifers are assumed to be homogeneous and isotropic. A homogeneous aquifer possesses hydrologic properties that are identical everywhere An isotropic aquifer is one with its properties independent of direction In reality such idealised aquifers do not exist

Discharge of groundwater

Groundwater in excess of the local capacity of an aquifer is discharged by evapotranspiration and surface discharge A route for direct discharge by transpiration to the atmosphere is provided whenever the capillary fringe reaches the root systems of vegetation. Some plants in arid and semi-arid conditions (phreatophytes) have root systems that extend downward more than 10 m to reach underground water If the water table or confined aquifer intersects the ground surface, water is discharged as surface flow If the discharge rate is low or the flow is spread over a large area, diffuse seepage may occur and water does little more than wet the ground from which it evaporates. Diffuse seepage along the banks of streams or lakes may, however, aggregate into a considerable volume and is often the main source of streamflow during dry periods. A large discharge from an aquifer concentrated in a small area is a *spring* Large springs are generally associated with fissures or caverns in the rocks. Springs associated with aquifers of large extent and moderate or low permeability usually flow at relatively constant rates. The discharge of a spring depends on the area contributing recharge to the aquifer and the rate of recharge. Most springs fluctuate in their rate of discharge. Perennial springs drain extensive permeable aquifers and discharge throughout the year, whereas intermittent springs discharge only during portions of the year when sufficient groundwater is recharged to maintain flow (see Figure 14.4).

Figure 14.4 *Sketch of a leaky or semi-confined aquifer*



A *groundwater basin* may be defined as a hydrogeologic unit containing one large aquifer or several connected and interrelated aquifers Such a basin may or may not coincide with a physiographic unit The concept of a groundwater basin becomes important because of the hydraulic continuity that exists for the contained groundwater resource In order to ensure continued availability of sub-surface water, basin-wide management of groundwater should be properly executed in a watershed

Groundwater movement

Groundwater in its natural state is invariably moving Except in large caverns and fissures. Groundwater flow is almost always laminar

$$g = KJ$$

where:

g = Specific discharge (m/day)
K = Co-efficient of permeability (m/day)
J = Slope of the water table

The above equation is also called *Darcy's Law* The actual velocity varies from point to point through the medium The average the actual velocity at which water is moving through an aquifer is given below

$$Vavg = \frac{Q}{nA}$$

where

Q = Flow rate (volume/ time)
A = Cross-section of the aquifer
n = Porosity of the medium (expressed in decimals)

The transmissivity, T is the flow in gallons per day (cu m/day) through a vertical section of aquifer 1 m wide under a hydraulic gradient of unity. The flow through an aquifer can therefore be written as

$$Q = KAJ = TWJ$$

where

K = Coefficient of permeability
A = Cross-sectional area of the aquifer
J = Slope of the water table
T = Transmissivity of an aquifer

$$T = \frac{K}{AW} = KB$$

where B is the thickness (depth) of the saturated zone

From Darcy's Law it follows that the rate of groundwater movement is governed by the hydraulic conductivity of an aquifer and the hydraulic gradient Assuming a productive alluvial aquifer with K=75 m/day and slope of the water table J=10 m/1000 m =0 01, then

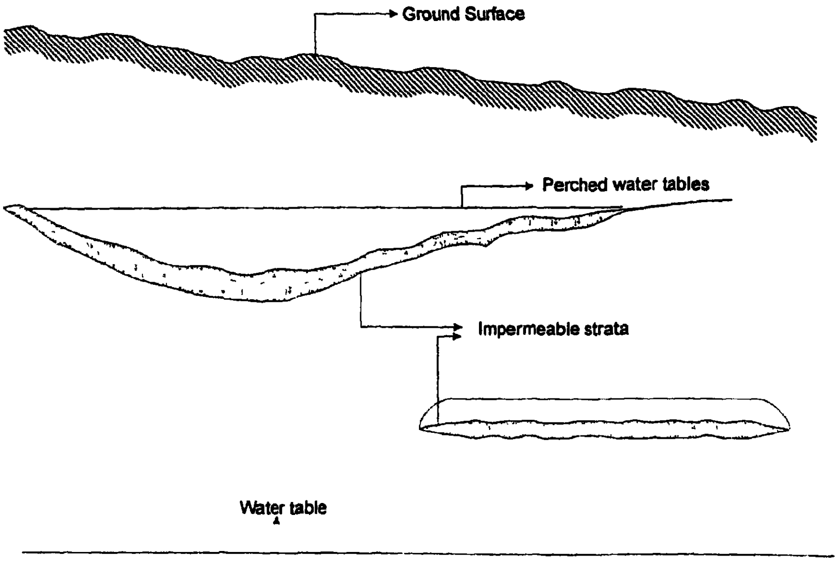
$$g=KJ= 75\ (0\ 01)=0\ 75 \text{ m/day } .\ 0\ 5 \text{ mm/min}$$

This demonstrates the sluggish nature of natural groundwater movement If the above flow occurs within and perpendicular to the large alluvial cross-section with length of aquifer 1000 m and height 50 m, then the total flow rate

$$Q= 50 \times 1000 \times 0.75 = 37{,}500 \text{ m}^3 \text{/day}$$

This depicts that groundwater is basically a massive slow moving body of water Groundwater velocity varies widely depending upon local hydrogeologic conditions with values ranging from 2 m/year to 2 m/day Usually, velocities tend to decrease with depth as porosities and permeabilities also decrease. Velocities can range from negligible to those of turbulent streams in underground openings within basalt and limestone. Mechanism such as wells and drains act to accelerate flows (see Figures 14.5 and 14.6).

Figure 14.5 *Sketch of perched water tables*



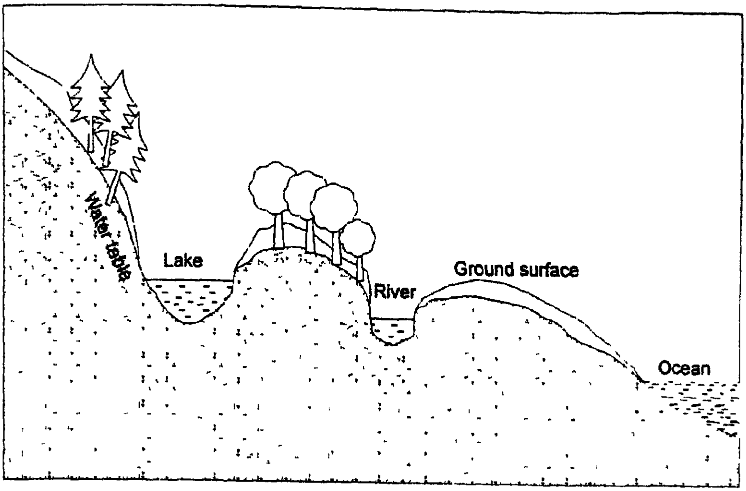
Yield of groundwater

An aquifer undisturbed by pumping is in approximate equilibrium. Water is added by natural recharge and removed by natural discharge. In response to periods of abundant precipitation and recharge, the water table rises, and in response to periods of drought the water level declines. The response time may be longer than annual weather cycles because of the slow flow rates in the sub-surface. Over long periods of time the rates of recharge and discharge tend to remain in approximate balance When a well is put into operation, new conditions are created. The flow system over a period of time, approach a level of equilibrium if the recharge can balance the pumping. Excessive withdrawals can cause increased pumping costs for existing wells, harmful depletion of streamflow, paucity of water in the portions of the aquifer that cannot be easily recharged and intrusion of lower quality water The concept of safe yield has been used to express the quality of groundwater that can be withdrawn without impairing the aquifer as a water source, causing contamination or creating economic problems from increased pumping life Determination of a safe yield for a given aquifer is practically difficult to ascertain

Surface and sub-surface investigation of groundwater

Groundwater recharge and management in watershed area is a very essential aspect of bal-

Figure 14.6 *Variations in depth of the groundwater table*



anced and harmonious resource utilisation. It is a need-based scientific strategy and begins with the assessment of:

— Area specific additional needs of groundwater for various activities.

— Water availability in different locations and seasons in micro-watershed.

— Mechanism most appropriate to groundwater recharge and service area to meet the demands for sustainable development

Although groundwater cannot be seen from the earth's surface, a variety of techniques can provide information regarding its occurrence and even its quality from surface or above-surface locations. It is simple to go ahead with SW.C measures like erosion control, runoff control, gully control measures under watershed treatment plan without prior technical investigations. But, assessment of groundwater and its recharge has to be planned in advance with the battery of investigations. Most of the methods and measures for groundwater management and recharge are expensive and may be a fiasco if not properly pre-planned. Surface investigations of groundwater are seldom more than partially successful in that results usually leave the hydrogeologic picture incomplete. They are normally less costly than sub-surface investigations Groundwater recharge measurements are important for judging the hydrogeological characteristics of watershed/basinal area Groundwater recharge measurements also play an important role in a host of other plans and decisions.

Estimation of groundwater recharge is such a domain of scientific activities that no single comprehensive estimation technique has yet been identified from the spectrum of methods available All these techniques give false positive and false negative results Thus, only limited progress has been made in groundwater exploration technology in the last 30 years Geo-physical techniques have been available for a considerable period of time but the most useful and commonly used geo-physical methods, which may be effective in exploration, are far from perfect It is very essential to be kept in mind by the project implementing agency that unless exploration is carefully planned and costed, expenditures may be far in excess of actual requirements and unjustifiable when compared to the value of the developed resource Detailed groundwater resource evaluation studies are expensive in terms of both funds and time and it is relatively rare that the quantified estimate has high degree of accuracy It should be decided in advance, what level of groundwater resource evaluation is necessary and cost effective for any given situation.

The massive groundwater development which has taken place in India during the past three decades (40% of total irrigation in India is from groundwater) has been achieved without detailed groundwater evaluation studies. Nevertheless, the development has been achieved with very few mistakes which could have been avoided by detailed resource evaluation

There are a number of methods to compute and study the groundwater resource and recharge as described below·

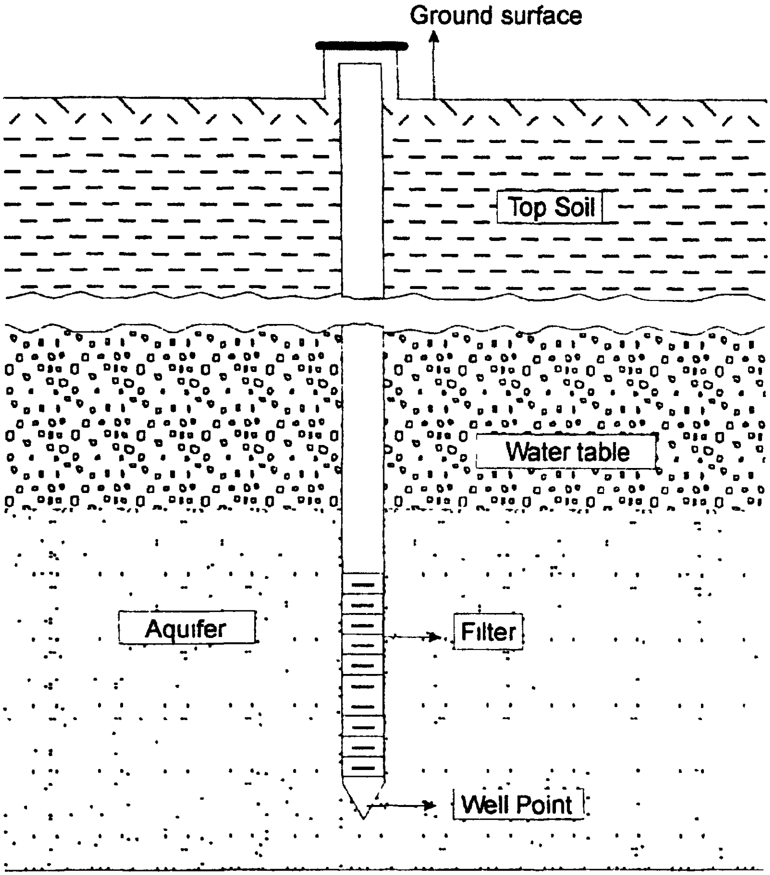
Estimation of groundwater

One of the most important investigations to be carried out before sub-surface design of a basin is the water table position and fluctuation The depth of water in an observation well on the other hand indicates the hydrostatic head of the entire underground soil profile to the depth of the well The number, type and location of observation well depends upon the information required, seriousness of the problem, extent of the area affected, time and fund available for investigation etc. If observations are to be recorded for a short period from a small area, auger holes can serve as temporary observation wells. If they are to be used for longer period, the holes may be provided with casing pipes and screens. If drainage investigation is to be conducted for a large basin, more permanent type of observation wells should be constructed Generally 3.75 cm diameter MS or GI or PVC pipes with screens at suitable depths are most suitable The observation wells should be drilled following standard methods. Even dugwells may be used for groundwater observation For detailed and accurate investigation, observation wells should be located in grids Water table readings should be recorded at frequent intervals of one week or fortnight using suitable method (see Figure 14 7)

The simplest way of taking measurements is by dipping a measuring tape marked with chalk inside the water in the observation well The water wets the chalk mark on the tape clearly and the difference of this reading from that at the top of the pipe gives the water table depth For easy lowering of the tape and its proper stretching, a suitable weight should be tied at the end of the tape A battery operated electrical signalling device can give more precise measurement While conducting topographic survey, the reduced levels (RL) of the top of all observation wells should be determined These are the reference points from where all water table readings should be taken

Finally these readings are converted to reduced levels Then, the groundwater contour map similar to topographic map is drawn A groundwater contour is an imaginary line passing through points of equal elevation of groundwater table. The groundwater contour

Figure 14.7 *Sectional view of a simple driven well*



map shows the elevation of water table at all points of equal elevation in the drainage basin at a particular period of the year It also shows the direction of groundwater flow, the locations of high and low groundwater levels etc For different periods of the year, different groundwater contour maps should be prepared Also water table hydrograph may be prepared The relation of this hydrograph with rainfall, irrigation, runoff or other hydrological phenomena may help to find out possible causes of water table rise or fall

Pumping test

This test is one of the most useful means of determining hydraulic properties of aquifers and confining beds It may yield reliable result, which in general are representative of a large area than single point observation It is important to pay special attention to the conditions and limitations of the various methods of analysis

The pumping tests are carried out to either determine the hydraulic characteristics of aquifers and confining layers or the well characteristics In the former case the test is called as *Aquifer Performance Test*. In the other type of tests, the specific capacity and other well characteristics, e.g , well loss, etc., can be determined by pumping the well with varying discharge. Such tests are called as *Step Drawdown Test* or *Well Test* and in this case instead of aquifer, well is tested

In an aquifer test, the well is pumped at a constant rate and the drawdown caused due to pumping is noted in pumping well and in one or more observation wells The number of pumping tests to be performed, the site of those tests and the general set up depend upon the kind of problem to be solved, the amount of information that is desired and funds available for the test programme A prior knowledge of the geohydrological condition is essential before the pumping test is carried out. A knowledge of thickness and nature of aquifer, boundary conditions, and direction of groundwater flow is essential.

The test is carried out at a place which is representative of the area for which aquifer characteristics are to be determined Care has also to be taken that the pumped water does not return to the aquifer. The pumping well should have full penetration so that the screen extends upto the bottom of the aquifer In case this is not feasible, necessary correction for partial penetration has to be made in the analysis of test data At least one observation well is essential to record the drawdown during pumping test However, for having a better idea of the aquifer characteristics more observation wells should be installed, so that the drawdown data can be analysed by both time-drawdown and distance-drawdown methods Three observation wells are usually recommended The distance of the observation wells from pumping well would depend upon the type of aquifer. In confined aquifer, where the cone of depression expands faster, the observation wells can be kept upto a distance of 300 m from pumping well In the case of unconfined aquifer, where the propagation of hydraulic head losses is rather slow, the observation wells may be kept within a distance of 100 m The distance of the observation well will also depend on the permeability of aquifer

In uniform and homogeneous aquifers the observation wells should screen the same horizons as the pumping well. In non-uniform aquifers with intercalated clay beds, the observation wells should screen the overlying and underlying horizons also in order to find out the possibility of hydraulic continuity between the tested aquifer and other horizons The duration for which the test should run depends upon the type of aquifer and the degree of accuracy desired in determining aquifer characteristics The test may be carried out till equilibrium conditions have been reached However, this may not be feasible in all cases, especially in unconfined aquifers In confined aquifers the test may be carried out for about 24 hours, while in unconfined aquifers the test should be of 3-6 days duration Long duration pumping test data are also helpful in determining the nature of aquifer and boundary conditions

The circular orfice weir is the most commonly used device to measure the rate of discharge from a turbine or centrifugal pump The rate of discharge can also be measured by using rectangular weirs The discharge rate should preferably be kept constant throughout the test The discharge rate can be kept constant by using a valve in the discharge pipe The most important part of a pumping test is to measure the drawdown in observation wells and pumping well These measurements should be taken several times during the test Since water levels drop fast during the early part of pumping, water level measurements should be taken at brief intervals in the beginning, with the time between readings being gradually increased as pumping continues The time interval of readings in the beginning (for the first one hour) vary from 1 minute to 5 minutes and this is gradually increased to 10, 30 and 60 minutes During recuperation test, the recovery of the water level is faster immediately after the pumping has stopped. The time interval of readings is gradually increased as the time since pumping stopped increases. The water levels during a pumping test are measured by using a wetted tape, air line, electric sounder or by automatic water level recorders Most commonly a chalk coated tape is used

There are broadly speaking two types of pumping test methods for determining aquifer characteristics One is known as *Drawdown Method*, and the other is *Recovery Method*. In the former method, drawdown data since pumping started is collected, while in the latter method the rate of recovery since pumping stopped is noted.

(a) Theim's equilibrium method

$$T = \frac{2\,30\ Q\ \log(r_2/r_1)}{2\,\text{pie}\,(S_1 - S_2)}$$

where

T = Co-efficient of transmissibility (m^2/day)

Q= Rate of discharge of pumped well (m^3/day)

r_1 and r_2 = Distance from the pumped well to the respective observation wells (m)

s_1 and s_2 = Drawdown in the observation wells at r_1 and r_2 respectively (m)

The derivation of the formula is based on the following assumptions

(a) the aquifer is homogeneous, isotropic and of infinite areal extent,
(b) the discharging well penetrates and receives water from the entire thickness of the aquifer;
(c) the co-efficient of transmissibility is constant at all times and at all places;
(d) pumping has continued at a uniform rate for sufficient time for the hydraulic system to reach a steady state (i e , no change in rate of drawdown as a function of time) condition,
(e) the flow is laminar; and
(f) the aquifer is confined.

The procedure for application of Theim's equation is to plot drawdown data, after the system has reached a steady state condition, collection from different observation wells on a semi-log paper, where drawdown is plotted on the arithmetic scale and distance on the log scale The graph, thus obtained, is known as distance-drawndown graph If the various assumption, as listed above hold good then the data plot should lie on a straight line or the best fitting straight line can be drawn through the plotted points

(b) Theim's recovery formula

After pumping stops, the water level in pumping and observation wells start recovering The rate of recovery will be more in the beginning The difference between the observed water level (during recovery) and the non-pumping water level (prior to pumping) is known as *residual drawdown* The Theim's equation for recovering period can be written as

$$T = \frac{2.30\,Q\ \log(t_2/t_1)}{4\,\text{pie}\,(S_1 - S_2)}$$

where:
T = Coefficient of transmissibility (m^2/day)
Q = Rate of discharge of pumped well (m^3/day)
t_2 = Time since pumping started
t_1 = Time since pumping stopped
s_1 and s_2 = Drawdown in the observation well at t_2 and t_1 respectively (m)

Geologic studies

These studies enable large areas to be rapidly and economically appraised on a preliminary basis as to their potential for groundwater development A geologic investigation begins with the collection, analysis and hydrogeologic interpretation of existing topographic maps, aerial/remote sensing photographs, geologic maps and logs and other pertinent records This should be supplemented, when possible, by geologic field reconnaissance and by evaluation of available hydrologic data on streamflow and springs, well yield, groundwater recharge, water quality, etc Such an approach should be regarded as a first step in any investigation of sub-surface water because no expensive equipment is required Also, information on geologic composition and structure defines the need for field exploration by other methods Knowledge of the depositional and erosional events in any area may indicate the extent and regularity of water bearing formation The type of rock formation will suggest the magnitude of water yield to be expected. Geologic history of an area may reveal aquifers beneath unsuitable upper strata, the continuity and interconnection of aquifers or important aquifer boundaries. The nature and thickness of overlying beds will enable estimates of drilling depths to be made Confined aquifers may be noted. Landforms can often reveal near-surface unconsolidated formations serving as aquifers Impermeable barriers to sub-surface flow can also be mapped from surface traces

Remote sensing

Photographs of the earth taken from satellite at various electromagnetic wave lengths can provide useful information regarding groundwater conditions There are immense possibilities of utilising the modern techniques of remote sensing as an aid to provide additional hydraulic and other information that are often not readily obtainable on the ground The main advantages of remote sensing are

(a) Obtaining of permanent pictorial record of the terrain features in a regional and synoptic overview, with possibility of speedy repeat coverage through satellite images This enables regional features having a bearing on water resources to be interpreted and deciphered more readily Regional surveys can be accomplished more speedily and effectively using remote sensing as compared to conventional ground surveys alone

(b) Possibility of a re-study of terrain features over large areas, if necessary, and analysis of the trend and intensity of the dynamic hydrologic processes such as floods, using sequential pictures Detecting changes in the area with time

(c) Multiband pictures provide for better terrain analysis

(d) The additional hydrologic 'clues' and information obtained by remote sensing, when combined and used in conjunction with field surveys, help enhance the survey results. Field traversing can be better planned and is also minimised by the use of remote sensing methods. This makes surveys economic and speedy.

(e) Integrated basin-wise hydrologic studies can be facilitated. The study of water resources of a region requires a knowledge of the nature of rocks and materials occurring therein, structural disposition, geomorphic set-up, the surface and groundwater conditions and climatic conditions, among others. These can be accomplished with remote sensing techniques.

Stereoscopic pairs of vertical aerial photographs, photomosaics, can all be used in interpretation of terrain conditions for water resource studies. Infra-red photographs are useful in delineating surface water bodies more sharply Thermal infra-red imagery and data help in the study and mapping of surface water temperature zones, locating hot springs, detecting groundwater leakage along coasts, and buried channels of shallow depths (2-3 m)

Visual interpretation of aerial and satellite pictures using standard interpretation keys/criteria can aid in the deciphering of specific site conditions such as location of spring and seepage zones (dark tone, lush vegetation clusters, abrupt appearance of water course at the base of hills), infiltration/recharge zones for groundwater (dry channels, abruptly ending streams), effluence (stream bank moisture), flooding and water logged areas, etc They also act as a guide to further field studies, location of likely exploration sites for groundwater, selection of gauge sites for hydrologic observations, etc Remote sensing techniques allow the assessment of water resources more readily in an integrated manner

Hydro-morphogeologic maps depict the important geomorphic units, landforms and underlying geology so as to provide an understanding of the processes, materials/lithology, structures and geologic controls *vis-a-vis* groundwater occurrence as well as prospects Such maps depicting prospective zones for groundwater targeting are essential, as base, for planning and execution of groundwater exploration. Hydro-morphogeologic studies from satellite images can be accomplished by following approaches (modified after Howe, 1958)

(a) Imagery interpretation, topographic map analysis followed by preparation of drainage base map Drainage analysis, morphometry, deciphering and delineation of stream features such as braided courses, influent and effluent reaches of rivers, drainage patterns and anomalies, delineation of infiltration recharge and spring or seepage zones

(b) Hydro-morphogeologic mapping-terrain analysis leading to landscape division and delineation of landform units, *vis-a-vis* rocks and materials composing the units, the structure and their controls on hydrologic conditions, identifying and marking of paleo-channels, fluvial forms/deposits providing clues to groundwater conditions, selecting key areas for ground checking and hydrogeological data gathering over the delineated landform units Extending the information gathered to areas of similar morphogeologic units within a given geo-environmental setting

(c) Delineation of surface materials, and soil types according to physiography and vegetation/land use, and their correlation with surface and sub-surface water conditions

(d) Delineation of surface water bodies, swamps and springs.

(e) Review of existing literature relevant to the investigation, study of well logs, pump test results, geologic reports, etc.

(f) Field check and field data-gathering, including geologic and geomorphic verification, hydrologic and hydro-meteorological data collection.

(g) Delineation of hydro-potential target zones indicating area likely to possess good prospective water bearing formations and deposits such as coarse semi-consolidated sandstones, terrace deposits, fans and alluvial plains, etc., based on remote sensing combined with collateral/field data.

(h) Preparation of hydro-morphogeological survey and final report-embodying highlights and results of study, assessment of groundwater prospects in study area, and indicating areas for future exploration according to groundwater situation classes, as well as areas suitable for exploiting surface water. Conclusions and recommendation-suggestions for proper follow-up studies for optimal water resource development, utilisation and conservation in the area.

In granular (consolidated) sedimentary rocks with development of open fractures, faults and weathering, groundwater possibilities are moderately good while highly compacted, cemented and folded rocks have poor prospects. Gently inclined, semi-consolidated sandstone formations (occupying cuestas) form good aquifers in down-dip sectors Unconsolidated granular materials like gravel and coarse-to-medium sand deposits are highly prospective aquifers Recharge areas over such deposits can be easily located by a pictorial analysis of drainage features (disappearance of surface flow, dry streams) and related terrain analysis Patterns of groundwater bearing forms/deposits and formations, such as alluvial fans (coarse deposits) terrace deposits (silt, sandy, gravels), water bearing sandstones, intemontane valley deposits, abondoned channels (sands), etc., can be readily recognised in remotely sensed data

Crystalline, hard rocks hold groundwater depending on the depth and extent of weathered materials overlying unweathered bed rock (variable pediment zones), and the size, nature, intensity, orientation and inter-connection of joints, fractures, fissures, and faults in these rocks Study of fractures, their pattern, density, frequency, nature ('open') or 'closed') and orientation, extension into covered areas using airphoto and satellite picture analysis are specially useful in targeting groundwater in hard rock areas 'Open' fracture zones are good yielders of groundwater from wells located along them Geomorphic mapping of outcrop and weathered zones, as well as delineation of fault-fractures zones are known to yield good quantities of groundwater in such areas Deeper cavities and enlarged joints creating secondary porosity allow the occurrence of good amounts of groundwater therein Internal drainages are indicated over limestone terrain by sink/shallow holes, which imply possibility of large amount of sub-surface water occurrence in solution caverns, cavity inter-connections, sub-surface channel ways, etc

In many places with some exceptions, it is observed that wells located in deeper weathered pediments and valley fills are more productive from groundwater point of view Recharge is good, water levels are relatively shallow, and large dia-dug/dug-cum-bore wells are suitable in such areas, specially, if they are traversed by lineaments Major lineaments and their inter-sections in pediplain areas are very prospective for locating borewells Fault zones are also good Infilled channels traversed by lineaments are very good for targeting well sites

In Jhabua, the thematic maps on 1 50,000 scale prepared from satellite imagery include

(a) geology and lineament map, and
(b) hydro-geomorphological map

These maps along with land slope and land use thematic maps were used by the district authorities and PIAs in field surveys to prepare groundwater table and contour maps along with land capability map They helped in demarcation of:

— recharge zone,
— transition zone, and
— discharge zone, in a milli-watershed/micro-watershed

Usually, thematic maps on 1:50,000 scale serve the purpose For detailed planning, maps on 1 12,500 scale can be effectively used. For hydro-morphogeological investigations using satellite imagery, the best results are obtained by comparative study of features on imagery in the green, red and near infra-red bands. Vegetation, land use, geomorphological and geological features, water depth and turbidity is clearly viewed on green band imagery Surface water bodies and soil moisture are shown in better contrast on near infra-red band imagery

Hydro-morphogeologic mapping approach using visual analysis of satellite imagery and field checks for groundwater survey has been successfully used. The approach is very useful for planning groundwater management and artificial recharge in watershed areas

Electric resistivity method

The electric resistivity of a rock formation limits the amount of current passing through the formation when an electric potential is applied It may be defined as the resistance (in ohms) between opposite faces of a unit cube of the material If a material of resistance (R) has a cross-sectional area (A) and a length (L), then its resistivity can be expressed as

$$r = \frac{RA}{L}$$

Units of resistivity are ohm-m Resistivity of rock formation vary over a wide range, depending on the material, density, porosity, pore size and shape, water content and quality, and temperature. There are no fixed limits for resistivities of various rocks (igneous and metamorphic rocks yield values in the range of 10^2 to 10^8 ohm-m) In relatively porous formations the resistivity is controlled more by water content and quality within the formation than by rock resistivity For aquifers composed of unconsolidated materials, the resistivity decreases with the degree of saturation and the groundwater

The procedure involves measuring a potential difference between two electrodes resulting from an applied current through two other electrodes outside, but in line with the potential electrodes Electrodes consist of metal stakes driven into the grounds If the resistivity is uniform everywhere in the sub-surface zone beneath the electrodes, an orthogonal network of circular arcs will be formed by the current and equipotential lines If the spacing between electrodes is increased a deeper penetration of the electric field occurs and a different apparent resistivity is obtained Since, changes of resistivity at great depths have only a slight effect on the apparent resistivity compared to those at shallow depths, the method is seldom effective for determining actual resistivities below a few hundred metres Resistivity surveys can cover vertical variations (soundings) at selected locations by varying electrode spacings They are conducted to obtain horizontal profiles of apparent resistivity or apparent-resistivity maps of an area by adopting a constant electrode spacing

Areal resistivity changes can be interpreted in terms of aquifer limits and changes in groundwater quality, whereas sounding surveys may indicate aquifers, water tables, impermeable formations and bedrock depths.

Any factor that disturbs the electric field in the vicinity of electrodes may invalidate the resistivity measurements. Of all surface geophysical methods, electric resistivity has been applied most widely for groundwater investigations. Portable equipment and ease of operation facilitates rapid measurement Where sub-surface conditions are relatively homogeneous, the technique can be employed to detect the water table as the top of a relatively conductive layer. An important new application of resistivity surveys involve defining areas and magnitudes of polluted groundwater.

Other surface and sub-surface investigations

Seismic refraction method.
Gravity and magnetic methods
Aerial photography.
Environmental/injected radio-isotope methods
Environmental/injected stable-isotope methods
Test drilling
Geophysical logging
Resistivity logging.
Spontaneous potential logging
Radiation logging.
Temperature logging.
Caliper logging
Fluid conductivity logging
Fluid velocity logging.
Acoustic logging
Tracer test for groundwater flow.
Groundwater level fluctuations
Groundwater quality

Artificial recharge of groundwater resource

It may be defined as augmenting the natural movement of surface water into underground formation by some method of construction of structures, by spreading of water or by artificially changing natural conditions Numerous methods of artificial recharge are available to PIA The choice of a particular method depends on local topographic, geologic and soil conditions, the quality of water to be recharged, the ultimate water use, land value and climatic conditions

The artificial recharge serves following purposes in any watershed:

(i) maintain or augment the natural groundwater as an economic resource,
(ii) coordinate operation of surface and groundwater reservoirs,
(iii) combat adverse conditions, such as progressive lowering of groundwater levels, unfavourable salt balance and saline water intrusion,
(iv) provide sub-surface storage for local or imported surface waters;
(v) reduce or stop significant land subsidence,

(vi) provide a localised sub-surface distribution system for established wells,
(vii) provide treatment and storage of reclaimed waste water for subsequent re-use.

The Integrated Watershed Development Programme aims to place adequate water underground from surface flow and runoff All erosion control and water harvesting SWC measures achieve this objective.

The following are the favourable conditions for natural or artificial recharge:

(i) Formation of sand, gravel or highly fractured rocks either underground or exposed over a large area or in stream channels.
(ii) The presence of caverns, fractured or faulted zones or numerous small cavities in rock formations (limestone areas either underground or exposed) on the land surface or stream channels
(iii) The absence of barriers for horizontal or vertical movement of groundwater.
(iv) Feasible locations for installation of recharge wells, dams, diversions or other recharge structures.
(v) Wide braided streams, broad alluvial fans and glacio-fluvial deposits may present excellent opportunities for water spreading A variety of methods have been developed to recharge groundwater artificially The most widely accepted and practised methods are water spreading methods. These methods include releasing water over the ground surface in order to increase the quantity of water infiltrating into the ground and then percolating to the water table. Numerous factors affect the recharge, length of time water is in contact with soil is most important The spreading efficiency is measured in terms of the recharge rate which is expressed as the velocity of downward water movement over the wetted area.

The following work plan should be prepared by the PIAs.

(i) Working out exact number of different structures required for artificial recharge.
(ii) Preparing a lay out plan on appropriate scale to mark locations of different structures and source of conveyance system
(iii) Pinpointing all the recharge structure sites and conveyance system layout on the ground.
(iv) Preparing design specifications and required drawings of all structures.
(v) Identification of various materials and equipments necessary to be deployed
(vi) Workout time schedules for completion of various stages of the scheme
(vii) Identification of the self-help groups which will execute the scheme

The project plan should include.

(i) Detailed background, including purpose and scope, technical feasibility and objective set
(ii) All physical details of the work including layout plans, drawing specifications of structures and materials
(iii) An execution plan indicating phasing, work and time schedule, PIA member-wise responsibilities, etc
(iv) Financial allocations and technical supervision
(v) Details of monitoring and evaluation systems and operations.

Groundwater budgeting for a particular basin can be very useful for efficient groundwater management in watershed areas (Chart 14 1)

Chart 14.1 *Groundwater budgeting*

The groundwater budgeting for a particular basin is to be calculated based on the norms recommended by the National Groundwater Estimation Committee, wherever adequate data are available

Following parameters are to be considered for budgeting the groundwater reserves in a particular basin:

(i) Recharge through rainfall = Total area x water level fluctutaion x sp yield
(ii) Recharge due to seepage from canals (unlined and lined)
(iii) Return seepage from surface water irrigation
(iv) Seepage from tanks /lakes/ ponds
(v) Contribution from influent seepage normal monsoon rainfall
(vi) Normalisation of monsoon rainfall recharge = $\dfrac{\text{Normal monsoon rainfall}}{\text{Monsoon rainfall of the year}}$
(vii) Non -monsoon rainfall recharge
(viii) Potential groundwater resources in flood prone areas

Total Annual Recharge (mcm) =
Recharge during monsoon
+
Non-monsoon rainfall recharge
+
Seepage from canals during non-monsoon
+
Return flow from irrigation during non-monsoon
+
Inflow from influent rivers
+
Recharge from tanks / lakes / ponds / percolation tanks

Potential groundwater resources = Potential recharge in water logged and shallow water table areas + Potential GW resource in flood prone areas

Total groundwater resources = Total annual recharge + potential groundwater resource (in mcm)

Annual utilisable groundwater = Total groundwater resources x 0 85
Resources for irrigation (mcm)

Gross annual groundwater draft (in mcm) through various structures
— Dugwells
— Dugwells with pumpsets
— Shallow tubewells
— Deep tubewells
— Others

Net annual groundwater draft (mcm) = 70% of gross annual groundwater draft/5

Groundwater balance = Annual utilisable groundwater resource for irrigation-net annual groundwater draft

Categorisation of block/taluk based on the level of groundwater development

Level of groundwater development as on date (%) = $\dfrac{\text{Annual net groundwater draft} \times 100}{\text{Annual utilisable groundwater resource for irrigation}}$

Contd

Chart 14.1 *Contd*

Yearly annual rate of groundwater development % = b

$$\text{Net groundwater draft at year 5} = \frac{\text{Annual net}\,(1 + 5b)}{100}$$

$$\text{Level of groundwater development at year 5 (\%)} = \frac{\text{Net groundwater draft at year } 5 \times 100}{\text{Utilisable groundwater resource for irrigation}}$$

Categorisation

<65 % = White or safe

<65-85% = Grey or semi-critical

>85 % = Dark or critical

(For further details please refer Groundwater Estimation Committee Report)

Basin method

Due to their general feasibility, efficient use of space and ease of maintenance, the basins are most favoured artificial recharge structures in a watershed. Water is recharged by releasing it into basins formed by construction of dykes or levees or by excavation. Generally, basin sizes and shapes are based on land surface slope. Most basins require periodic maintenance to improve infiltration rates by scarifying or scrapping the bottom surfaces when dry. When local runoff is being recharged, a single basin is normally sufficient. But where streamflow is being diverted for recharge, a series of basins often parallel to the natural stream channel is most advantageous. Water from the stream is led by a ditch into the uppermost basin. It spills into the second basin and the process is repeated through the entire chain of basins. From the lowest basin excess water if any is returned to the stream channel. This method permits water contact over 70-90% of the gross area. Multiple basins provide for continuity of operation when certain basins are non-functional due to drying and maintenance. Also, in a series, uppermost basins may be reserved for settling silt.

Percolation tanks collect surface runoff in small storage structures to recharge groundwater. Studies have revealed that these structures release 50% of the designed storage capacity to underlying groundwater to an influenced area of 1.5 sq km. These are constructed for a impounding surface runoff to create small storage for inducing recharge to groundwater through percolation. They are constructed at suitable places across *nallas*. The site should be relatively flatter *nalla* reach, the slope of *nalla* not exceeding 2 %. The catchment of the structure should be above 40 ha. To prevent breaching of the bund of the percolation tank, an emergency spillway may be provided. The site for construction of the emergency spillway should preferably be in hard rock. However, the bund of the percolation tank need be adequately permeable.

Coming to the design, the top width of the bund should be above 1 m. A freeboard of one-third of impounding depth, but not less than 1 m may be provided. The bund section should include a core wall and puddle trench on the lines indicated for earthen dams. The emergency spillway of cut outlet type may be provided depending on the drainage of the area.

Sub-surface dykes are structures constructed below ground level to arrest the natural sub-surface groundwater flow. They conserve groundwater within aquifer itself The design involves excavation of trench down to impervious layer and construction of a diaphram wall. The crest of the dyke is kept few centimetres below ground level. Concrete plastered brickwall and clay are commonly used for construction of dykes.

Stream channel method

Structures and operations which spread water in a natural stream and thereby increase the time and area over which water is recharged from a natural channel It involves both upstream management of streamflow and channel modifications to enhance infiltration. Upstream reservoirs enable erratic runoff to be regulated and limit streamflow to rates that do not exceed the absorptive capacity of downstream channels. *Nalla* bunds, boulder check dams, gully plugs, etc , help in reducing the runoff in the stream. Improvements of stream channels may include widening, levelling, scarifying or ditching to increase infiltration Low checkdams and dykes can be constructed across a stream where these structures act as weirs and distribute the water into shallow ponds These structures are mostly temporary or semi-permanent in nature, constructed from locally available material They may be protected by vegetation, wire or boulder pitching Such works may quickly collapse when high runoff takes place in the stream

Ditch-and-furrow method

In this method, water is distributed to a series of ditches, or furrows that are shallow, flat bottomed and closely spaced to obtain maximum water contact area Contour trenches are most commonly used They may be staggered or continuous and usually follow the ground contour. Tree shaped ditches may be constructed where main canal successively branches into smaller canals Lateral ditches are constructed in a series extending laterally from the main canal Gradient of these ditches should be sufficient to carry suspended material through the system Deposition of fine-grained material on surfaces should be avoided Numerous ditch structures are available, a particular structure or ditch plan should be selected which is appropriate for the configuration of the local area A collecting ditch is needed at the lower end of the site to convey excess water back into the mainstream channel This method has been adapted for irregular or undulating terrain It provides water contact to less than 10% of the gross area

Floating method

When flat topography like vast unutilised wasteland is available in the watershed then water may be diverted through grassed waterways or diversion channels to such areas Canals and earth distributing gullies are usually needed to release the water at intervals over the upper end of the flooding area The aim should be to form a thin sheet of water over the land which moves a minimum velocity to avoid disturbing the soil the infiltration of water is quite high Highest infiltration rates occur on areas with undisturbed vegetation and good soil depth Flood spreading costs least for land preparation To control the water at all times, earthen embankments or ditches should surround the entire flooding area The method could be tried but its applicability in Indian conditions is marginal, because most of the watershed do not have unutilised wastelands, as they are either encroached or some other intervention has already been planned out

Pit method

Excavation of pit into a permeable formation serves as an ideal facility for groundwater recharge As the cost of excavation and removal of material is high, use of abandoned excavation could be considered. This method could be very useful in watershed areas where shallow sub-surface strata like hardpans and clay layers are existing and downward passage of water is restricted The capital costs involved in excavation of pits could also be minimised by using them for purposes other than recharge The steep side slopes provide a very high silt tolerance Silt usually settles to the bottom of the pits leaving the walls relatively unclogged for continued infiltration of water Generally, non-silty water should be recharged, wherever possible, so as to minimise silt accumulation and periodic removal costs The pits could be 3-6 m deep and with side slopes of two/three horizontal to one vertical The bottom and side slope, may be covered with a 15 cm layer of natural gravel (3-8 mm size). The cleaning of silt should be periodically done

Recharge well method

These wells admit water from the surface to freshwater aquifers In short, its flow is the reverse of a pumping well but its construction may be different. Well recharging is recommended in watersheds where deep confined aquifers must be recharged, or in high agricultural intensive area where space for recharging is not available When water is admitted into a recharge well, a cone of recharge will be formed that is similar in shape but is the reverse of a cone of depression surrounding a pumping well Any silt carried by water into a recharge well is filtered out and tends to clog the aquifer surrounding the well Recharge water may also carry large amounts of dissolved air, reducing the permeability of the aquifer Recharge water may also carry contaminants-biological or chemical, into the aquifers In certain areas of Maharashtra, 10-30 cm diameter and 30-50 m deep recharge wells have been constructed in scores which are capable of accepting flows upto 10,000-20,000 m^3/day Recharge wells may show initial large intake rates followed by nearly constant or slowly decreasing values Greatest intake rates are found in extremely porous formations such as limestones etc

Injection well method

River and well water free from colloidal suspension could be pumped /injected into the deep aquifer of tubewell by pumping it through a pipe upto a depth of 50-60 m This is also an important technique for artificial recharge It may be used at a place where groundwater has been over-exploited

Tubewell recharge with perforated casing pipe

A cylindrical pit of 3 m diameter and 3-4 m deep is dug around tubewell casing pipe In the casing pipe, holes of 8-10 mm size at a distance of 3-4 cm are drilled Alternatively, old casing pipe is cut and at the cut-end, perforated pipe with additional holes is welded On the perforated casing pipe, coir rope is wrapped, which serves the purpose of filter Coir rope is to be replaced in 2-3 years times Around the casing pipe in a pit pebbles (30-40 mm) is filled in the lower one-third depth, followed by medium size pebbles (15-20 mm) upto two-third depth In the one third upper portion, sand of 2-4 mm size and a lining of boulders is packed on the outer periphery. Runoff water getting accumulated around the tubewell passes through sand bed filter, and finally enter the tubewell bore through coir filter reaching directly to deep aquifer strata to recharge.

Incidental recharge

Incidental or unplanned, recharge occurs where water enters the ground as a result of a human activity, whose primary objective is unrelated to artificial recharge of groundwater Water from irrigation, cesspools, reservoirs, canals, etc., may lead to incidental recharge. The quantity of incidental recharge normally far exceeds that deliberately accomplished by artificial recharge structures.

Control of groundwater outflow

Construction of underground checkdams
Cementing of discharging faces and prevention of leakage
Pressure injection grouting
Construction of cementing plugs
Sealing of spring faces.

Groundwater management in watershed areas

Maximum utilisation of groundwater resources require exhaustive planning and meticulous execution of treatment structures in an entire groundwater basin Basin is a very large structure or reservoir, so, utilisation of groundwater by one land owner affects the water supply of all other land owners Thus groundwater resource is also a common property resource and should be judiciously and harmoniously managed Management objectives based on geologic, hydrologic, economic, legal and financial considerations should be evolved in watershed areas. It goes without saying that the optimum economic development of water resources in an area requires an integrated approach for coordinated surface water and groundwater resources utilisation

Proper groundwater basin management encompasses development and utilisation of sub-surface water for economic or community purposes The desired aim is to obtain the maximum quantity of water at least cost Generally, when a water well is constructed, beneficiaries presume that production of water will continue over indefinite period of time, as groundwater resources are considered as renewable natural resources But this can only occur if there exists a balance between water recharged to the basin from the surface resources and water exploited from within the basins through wells Numerosity of groundwater resource utilisation points, like wells push the groundwater basin development to its recharging limits Further exploitation, appropriately called *groundwater mining*, without a management plan could eventually deplete the groundwater basin An underground reservoir can be made to function beneficially and indefinitely just like a surface reservoir It is a common knowledge that groundwater reservoirs formed by aquifers constitute invaluable water storage facilities, so a proper management of them in a watershed area should be given due importance The management plan should consist of provision of economic and continuous water supply to meet the ever-increasing demand of water for irrigation and domestic use from an underground water resource, of which only a small portion is perennially renewable The advantages and disadvantages of sub-surface reservoirs and surface reservoirs are given in Table 14 2.

Table 14.2 *Advantage and disadvantage of sub-surface and surface reservoirs (after U S Bureau of Reclamation)*

	Sub-surface reservoirs		*Surface reservoirs*
	Advantages		*Disadvantages*
1	Numerous large-capacity site are easily available	1	Very few sites are available
2	Slight to no evaporation loss	2	High evaporation loss even in humid conditions
3	Require little land area	3	Require large land area
4	Slight to no danger of catastrophic structural failure	4	Ever-present danger of catastrophic failure
5	Uniform water temperature	5	Fluctuating water temperature
6	High biological purity	6	Easily contaminated
	Disadvantages		*Advantages*
1	Water must be pumped	1	Water may be available by gravity flow
2	Storage and conveyance use only	2	Multiple use
3	Water may be mineralised	3	Water generally of relatively low mineral content
4	Minor flood control value	4	Maximum flood control value
5	Limited flow at any point	5	Large flows
6	Difficult and costly to investigate, evaluate and manage	6	Relative easy to evaluate, investigate and manage
7	Recharge opportunity usually dependent on surplus surface flows	7	Recharge dependent on annual precipitation
8	Continuous expensive maintenance of recharge	8	Little maintenance required on annual facilities

An integrated and comprehensive sub-surface water management plan should be arrived. Following steps or sequence of activities may be adopted:

(1) *Identification of problem* Lowering water levels, waterlogging subsistence, water quality degradation, percolation of wastewaters.

(2) *Formulate alternative management objectives* Aquifer management as part of the total water supply, water service at least cost, basin versus region, and social, economical and legal constraints

(3) *Define elements and management plan* Pumping locations and schedule, artificial recharge location and schedule, organisational and financial monitoring systems

(4) *Development for investigation* Preparation of report discussing alternative management plan

(5) *Select scope of investigation* Determine study area, schedule and level of study

(6) *Develop work programme for investigation* Identify what must be accomplished with emphasis on need for historic basic data, continued data collection, use of EDP techniques

(7) *Create planning organisation structure* Usually within the watershed organisation structure

(8) Commence and evaluate investigation results.

(9) *Project future water demand.* Present and future/applied and consumptive use demands for irrigation, domestic uses, etc.

(10) Surface and sub-surface exploration and assessment of water resources

(11) *Capability of extraction and recharge facilities* Inventorisation of existing extraction and recharge facilities and capability of modifying systems.

(12) *Aquifer boundary condition* Assessment of quantity and quality of sub-surface inflow and outflow.

(13) *Water distribution organisational considerations*: Water rights to user's, damages due to groundwater level lowering and waterlogging, distribution rules by the community, sanctions against violators.

(14) *Alternative plans for water resources management* Formulate plans considering physical and economic aspects like patterns and schedules of recharge and extractions, storage for infiltration of runoff, control of groundwater levels to avoid severe lowering and waterlogging, water quality, integration of total water resources system, cost-benefit analysis of interventions, etc

Following are the alternative basin yields of groundwater

(i) *Mining yield* If groundwater is exploited at a rate exceeding the recharge, a mining yield results. This yield must always be limited in time until the aquifer storage is depleted

(ii) *Perennial yield* The perennial yield of a groundwater basin is the rate at which water can be withdrawn perennially, under specified operating conditions, without progressive reduction of the water resource, development of uneconomic pumping conditions and degradation of groundwater quality.

(iii) *Maximum perennial yield* The maximum perennial yield means the maximum quantity of groundwater perennially available, when all possible methods and sources are developed for recharging the basin Thus, the more water that can be recharged, both naturally and artificially to a basin, the greater the yield To achieve the maximum perennial yield, the aquifer should be managed as a composite unit.

The management plan of groundwater should consider the variability of perennial yield The variations may be due to

1 change in the level of groundwater within a basin,
2 extent of natural and artificial recharge,
3 changes in location of pumpage sites,
4 rate of flow through the aquifer,
5 changes in vegetation and crops, and
6 changes in the purpose of pumping groundwater etc

Conjunctive use of surface and groundwater

Optimal and beneficial use can be obtained by conjuctive use involving coordinated and planned operation of both surface water and groundwater resources to meet water requirements in a manner, whereby water is conserved Surface storage in surface water harvesting reservoirs can fulfill the supply of annual water requirements and the groundwater storage can be retained primarily for cyclic storage to cover years of sub-normal precipitation During periods of above-normal precipitation, surface water is utilised to the maximum extent possible and also artificial recharged into the ground to augment groundwater storage and raise groundwater levels. During droughts limited surface water resources are supplemented by pumping groundwater thereby lowering groundwater levels. But there must be a space to store recharged water and there must be water in storage for pumping, when required. Table 14 3 below depicts various advantages and disadvantages of conjuctive use:

Table 14.3 *Conjunctive use of surface water and groundwater resources (after Clendever)*

	Advantages		*Disadvantages*
1	Greater water conservation	1	Greater power consumption
2	Smaller surface storage	2	Decreased pumping efficiency
3	Smaller surface distribution system	3	Greater water salination
4	Smaller drainage system	4	More complex project operation
5	Reduced canal lining	5	Artificial recharge is necessary
6	Greater flood control		
7	Smaller evapotranspiration losses		
8	Greater control over out-flow		
9	Better timing of water distribution		

The following basic principles of groundwater basin management produce an optimum water resource management (after Fowler)

1 The surface and underground storage capacities must be integrated to obtain the most economical utilisation of the local storage resources and the optimum amount of water conservation.
2. The surface distribution system must be integrated with the groundwater basin transmission characteristics to provide the minimum cost distribution system
3 An operating agency (say PIA/WDC) must be available with adequate power to manage surface water resources, groundwater recharge sites, surface distribution facilities and groundwater extractions

In certain cases, when water table is close to the ground surface, so that the growth of crop roots is inhibited, surface damage can remove the excess water. It increases effective root zone depth and reduces sodium and other soluble salts which are harmful to the plants in high concentration Sub-surface drainage can lead to more infiltration, thereby improving the soil structure and reducing the soil erosion hazards Sub-surface drainage may be defined as the removal of excess groundwater present below the ground surface Open ditches, buried drains, random system, parallel system, herringbone system, double main system, relief wells, mole drains, vertical drains, etc, are some measures which may be adopted for sub-surface drainage, if the excess drainage is urgently required to be removed from the watershed

Groundwater management and recharging is a less emphasised aspect The above sections have depicted that it should be given due importance in all integrated watershed treatment plan.

15

Nursery Raising and Community Plantation

Large-scale plantation in watershed area is essential, especially in the third and the fourth year. The quantum of saplings needed for plantation cannot be emphasised too much Taking the example of Jhabua district, watershed development programme is implemented under Rajiv Gandhi Mission on Watershed Development in 218 micro-watersheds on an area of 1 26 lakh ha. In the second and the third year, the requirement of saplings of various species was estimated to be 73 lakhs It was not possible to provide 73-75 lakh saplings from central or departmental nurseries. So, the technique of nursery raising was spread to all 264 villages in which watershed programme was being implemented With the help of self-help group (SHG) nurseries 80 lakh saplings of numerous species could be produced in 1996-98. The effort emphasised the fact the technique of nursery raising can be demystified and can be spread into remotest corners of watershed villages Nurseries in Jhabua were raised and maintained at three different levels

(a) *At the level of project implementing agencies* At milli-watershed level, PIA can raise nursery, specially for fulfilling the demand of those saplings of tree species which need special methods to raise It also fulfils the shortfalls at micro-watershed levels The size of the nursery could be such that it is sufficient to raise 2-5 lakh saplings

(b) *At the level of self-help groups* At micro-watershed level, SHGs consisting of 5-15 members, especially women groups, can be constituted These groups are imparted with training on techniques and management of nursery raising The watershed development committees provide inputs needed for raising and maintaining nurseries The final products (saplings) would be bought by WDC for plantations locally The profits generated would be given to the SHG The size of nursery can be such as to raise 15-25 thousand saplings Production of better quality saplings near the plantation area is possible through SHGs The cost of sapling is also quite less *vis-a-vis* open market rates The profits generated (generally in the range of Rs 10,000-20,000 for an effort of six months) act as additional remuneration to the SHG The activity would help in mobilising society and would reorient the community (see Plate 40)

Plate 40 *At micro-watershed level, SHGs consisting of 5-15 members (especially women groups) can take up nursery raising*

(c) *At the level of households*. Private nurseries at the household level could act as an extra source of income Well-aware BPL families, especially landless, may be selected to take up nursery raising at household level. The size of the kitchen garden nursery could preferably be such as to raise 5-10 thousand saplings The inputs are provided by WDC and the training on techniques and management is imparted by PIA The produce is bought by WDC for local plantation. BPL and landless families could effectively take up the job of nursery raising, and earn a livelihood

Selection of species for planting

The first step is to find out the preferences of beneficiaries in watershed areas. The selected species should cater to the fodder/forage, fuelwood, NTFP, timber, etc , demands of community. The species should fit into the edaphic conditions, climatic conditions, and socio-economic realities Various PRA tools are used to find out suitable, acceptable and preferred tree species for community plantation. An indicative list of such diagnostic tools is mentioned in Table 15 1

Information should also be gathered regarding

(1) community plantation sites
(2) user-groups/self-help groups
(3) indigenous management systems
(4) nursery location
(5) nursery establishment

(6) nursery operation
(7) land use management
(8) plantation operations

Such information can be gathered through various PRA tools in watershed areas

Table 15.1 *PRA methods for selection of tree species for community plantation*

1	Rating, ranking and scoring matrices (David Case 1990, Grandin 1988)
2	Pairwise ranking and wealth ranking (Maxwell and Bant 1995, Pretty et al 1995)
3	Semi-structured interviews (David case 1990, Pretty et al 1995, Na-Lampany, 1990)
4	Focus group/Interest group interviews (Fisher and Malla 1987, Glimour and Fisher 1991)
5	Participant-observation techniques (Fetterman 1989, Jorgensen 1989)
6	Community surveys community appraisals, group treks brainstorming workshops (Chamber et al 1989)
7	Historical profile analysis, socio-linguistic status discussions, open-ended stories, etc
8	Collecting indigenous technical knowledge (ITK), traditional systems of organisation (TSO), folk taxonomies, farmer classification, local custom analysis (Spradley and McCurdy 1972, Warsen et al 1989)
9	Sketch maps, thematic maps, map overlay analysis, aerial photography and analysis (Cerson 1987, Gupta 1989, Mascarenhas et al 1991, Mearns 1989, Pretty et al 1995)
10	Transact walks, transact analysis, transact drawing (Lighfod et al 1989)
11	Topical agro-ecosystem zoning (Conway, 1986)
12	Diagrams, pie and venn diagrams, resource diagrams (Conway 1989, Campbell and Gill 1991, Davis Case, 1989)
13	Biophysical assessment techniques (Bartlett and Nurse 1991, Nurse et al 1991, 1992)
14	Vegetation description methods (Metz 1991)
15	Strength-weaknesses-opportunities-limitations (SWOL) analysis (David Case 1990)
16	Other methods like rapid site description, field size estimates, slope inclination estimates, ecological-social-environmental indicator analysis, decision trees, calenders, timelines, flow charts and diagrams, time allocation studies, pattern analysis, historical mapping, games, popular theatre, community visual/sound production, ocular estimates, use of satellite imagery, survival surveys, community environmental assessment, unserialised posters, historical mapping, tape recording etc

Generally, in hilly catchments, where the aim is to get maximum yield of usable water in the streamflow, species with low transpiration rate should be selected In arid and semi-arid agro-climatic areas, hardy xerophytic species should be selected In localities, where due to degradation the ecology is moving retrogressively, leguminous species with dense foliage are preferred, on higher altitude plantations, conifers like fir should be mixed with broad-leaved species Species with leaves containing growth-inhibiting substance should be avoided Mixture of species at plantation site ensures natural resistance to insects, pests and fungi Mixture of species would be able to fulfil fodder, forage, firewood, NTFP, food and small timber demands of the community

Direct seeding

Possibilities of direct seed sowing should always be ascertained, as in many species direct seed sowing is possible This process is cheap and eliminates lengthy procedure required for nursery raising, transportation, planting, etc. It also improves the form of the tree and of the rooting pattern. However, a good seed supply is a must for this method, since certain amount of seed will always be wasted. Directly sown seedlings cannot be well cared for as seedlings in a nursery. Wastage of seeds are due to seeds being washed away by rain, being eaten by birds, or young seedlings being accidentally removed as weeds. There could be total failure, if there is an extended dryspell after direct sowing of seeds Re-sowing in such situation has to be resorted to This evidently calls for extra efforts and resources

For successful direct seeding in arid and semi-arid areas, following factors are crucial

(i) Good advanced preparation of site (land levelling, soil and water conservation measures, water harvesting structures, strip cultivation and weeding).
(ii) Synchronisation of sowing with the onset of rains
(iii) Optimum depth of sowing, with adequate protection from birds and rodents.

Direct seeding is recommended for species·

(i) Many seedlings are required
(ii) Fast initial growth of seedlings is seen
(iii) A good seed supply is available(so that wastage of some seeds may be recouped.
(iv) Seeds are large in size(since they are not easily washed away by rains)

Direct sowing is easy, quick and cheap but the requirement of seeds per unit area is large Climate, biotic factors and weed competition ultimately decide establishment of seedlings (Table 15 2)

Table 15.2 *Species which could be established by direct sowing or planting or both*

(i) Direct sowing species:

Anacardium occidentale
Lannea coromandelica
Leuceana leucocephala
Moringa oleifera
Parkinsonia aculeata

(ii) Entire planting species:

Acacia tortilis
Aesculus indica
Casuarina equisetifolia
Erythrina variegata
Eucalyptus camaldulensis
Eucalyptus tereticornis
Ficus auriculata
Grewia optiva
Michelia doltsopa
Morus serrata
Platnus orientalis
Prunus armeniaca
P cerasoides

Contd

Table 15.2 *Contd*

P persica
Psidium guajava
Tectona grandis

(iii) Direct sowing/entire planting species:

Acacia auriculiformis
A catechu
A Fanesiana
A leucophloea
A modesta
A nilotica sp cupresiiformis

A nilotica sp indica
Aegle marmelos
Ailanthus excelsa
Albizzia lebbek
A amara
A odoratissima

Alnus nepalensis
Artocarpus heterophyllus
A lokoocha
Azadirachta indica
Bauhinia purpurea
B racemosa
B variegata
B vahlii
Cassia fistula
C siamea
Celtis australis
Dalbergia latifolia
Dalbergia sissoo
Dendrocalamus strictus
T chebula
T myriocarpa
Zizyphus mauritiana

Prosopis cineraria
P juliflora
Pterocarpus marsupium
Robinia pseudoacacia
Santalum album
Saraca ashoka
Sesbania grandiflora
Emblica officinalis
Eucalyptus globulus
Grevillea robusta
Hardwickia binata
Holoptelea integrifolia
Jugalans regia
Kydia calycina

Mangifera indica
Melia azedarach
Mesua ferrea

Peltaphorum pterocarpum
Pinus roxburghii
Pithecelobium dulce
Shorea robusta
Swietenia macrophylla
Syzygium cumini
Terminalia tomentosa
T arjuna

If the seeds are sown very deep, the seedlings may not reach the soil surface after germination and may die If sown very shallow, then the seeds may be washed away in rains and may dry out during germination Generally, sowing depth of a seed is equal to the seed diameter It is important to sow the seed in proper time If there is a dry spell, a little supplementary watering may be needed Weeding of undesirable grasses, bushes and trees is equally important Pelletising seeds improve the chances for better seedling emergence

Decision as to direct seed sowing or sapling plantation depends upon.

(i) *Species* Certain species can be raised from sowing while others cannot

(ii) *Site condition* On difficult sites like steep slopes, landslides, degraded lands, sund dunes, planting gives better results than seed sowing

(iii) *Seed availability* Species whose seeds are in short supply or whose viability is usually low or which require pre-seed treatment, planting gives better results

(iv) *Funds availability* Where funds are scarce, direct seeding is a preferred mode.

On very adverse sites, e g , poor and exposed soil, hot and dry localities, landslips, waterlogged and saline areas, wind or water eroded areas, planting in long run is superior

Seed collection

Seeds should usually be collected from genetic-plus trees or from seed production areas Good quality of specific species seeds may be obtained from seed orchards Seeds of indigenous species may be collected in large quantities from available trees in the area This reduces cost of plantation It is important to be vigilant while collecting such seeds Primarily, there should be ample knowledge of seeding and seed selection Source of seed a is very important aspect Seeds from deformed, dead, dying or decayed trees should be rejected outrightly Stunted and dwarfed trees should be avoided during seed collection Overmature and young trees should similarly be avoided Seeds from healthy, tall, straight trunk trees should be preferred Such trees should be earmarked and demarcated while surveying the area before seed collection Seeds should not be collected from isolated trees as they produce less productive self-pollinated seeds Information regarding such trees should be maintained in a register Seed collection should be done from 10-15 mother trees Frequent seed collection should not damage the tree Seeds should be preferably collected in the middle of seeding period The time for seed collection of different species are given in Table 15 3

Table 15.3 *Seed collection time for certain species (trees/grasses)*

1	*Acacia auriculiformis*	March-April
2	*A catechu* (Khair)	December-March
3	*A nilotica* (Babool)	March, April May
4	*Albizia amara* (Custer)	April
5	*A lebbeck* (Kala siras)	January-March
6	*A procera* (Safed siras)	February-May
7	*Annona squamosa* (Sitaphal)	November
8	*Azadiracta indica* (Neem)	June July
9	*Bauhinia variagata* (Kachnar)	May June
10	*Butea monosperma* (Palash)	May
11	*Cassia siamea*	March, April
12	*Casuarnia equisetifolia*	December January, May June
13	*Chetentlus collinus* (Karra)	March April

Contd

Table 15.3 *Contd*

14	*Dalbergia sissoo* (Sissoo)	December, January, May, June
15	*Dendrocalamus strictus* (Bamboo)	March, May
16	*Dlonix regia* (Gulmohar)	January-March
17	*Eucalyptus hybrid*	December-May
18	*Emblica officinalis* (Anwla)	January, February
19	*Gmelina arborea* (Khamair)	May, June
20	*Holoptelea integrifolia* (Chirol)	April, May
21	*Leuceanla Leucocephala* (Subabool)	May, June
22	*Pongamia pinnata* (Karanj)	April, May
23	*Prosopis juliflora* (Vilayati babool)	April, May
24	*Tectona grandis* (Teak)	February, March
25	*Terminalia arjuna* (Arjun)	April, May
26	*Ailanthes excelsa* (Maharukh)	May, June
27	*Sesbania aegyptica* (Shaveri)	December-February
28	*Moringa oleifera* (Munga)	May, June
29	*Sesbania grandiflora* (Agatsya)	January, February
30	*Hardwickia binata* (Anjan)	April, May
31	*Syzizium cumini* (Jamun)	June
32	*Mangifera indica* (Aam)	June July
33	*Madhuca lalifolia* (Mahua)	June, July
34	*Ficus bengelensis* (Bad)	April, May
35	*Ficus religiosa* (Pipal)	April, May
36	*Anacarduim occidentale* (Kaju)	April, May
37	*Melia azedarach* (Bakayan)	February-May
38	*Nictenthus arbortrastis* (Harsingar)	January, February
39	*Parkinsonia aculeata*	December
40	*Pithecellobium dulce* (Vilayati imli)	April
41	*Psidium guajava* (Amrood)	November December
42	*Zizyphus jujuba* (Ber)	December January
43	*Pheronia elephantam* (Kaitha)	January-March
44	*Cenchrus spp* (Anjanghas)	October-February
45	*C Cetigerus* (Peela anjan grass)	October-February
46	*Crysopogon fulvus* (Senghas)	October
47	*Dicanthium annulatum* (Choti marvel ghas)	October
48	*Panisatum pedicilletum* (Dinanath grass)	October, November
49	*Sehimea nervosum* (Poniaghas)	October

Seed certification is essential for collected seeds It involves (i) seed testing, (ii) seed harvest, (iii) seed drawing, (iv) seed treatment, (v) seed production, and (vi) seed storage The detailed information about these aspects should be correctly gathered Generally, seeds should be sown as soon as they are collected.

Seed storage

If seeds are utilised just after the seed collection, then storage may not be required. Seed storage, though in most situation, is needed. Seeds can be categorised into orthodox and recalcitrant seeds. *Orthodox seeds* are those seeds which can be dried up to 5% moisture content without affecting germination capacity and can be stored for long duration *Tectona grandis* (Sagwan), *Acacia nilotica* (Babool), *Acacia catechu* (Khair), *Prosopis spp.*, *Albizzia lebbek* (Kala siras), *Albizzia procera* (Safed siras), *Dalbergia sissoo* (Sissoo), etc , are orthodox seeds *Recalcitrant seeds* are those seeds which can at most be dried upto 20-40% moisture cantent and cannot be stored for long duration (2 weeks) without affecting the germination capacity. *Mangifera indica* (Aam), *Sygygium cumini* (Jamun), *Azadirachta indica* (Neem), *Madhuca latifolia* (Mahua) *Shorea robusta* (Saal), *Melia azadarach* (Bakayan), etc., are recalcitrant seeds Such seeds should be used within a short period after collection. Species whose seeds mature in winters can be stored upto start of rainy season Oily seeds cannot be stored for a long period. Following points should be taken into consideration for seed storage.

(i) Seeds should be properly dried Dry seeds are more resistant to attacks by insects, fungus, etc.
(ii) Seeds should be stored for long duration in deep freeze or cold storage
(iii) Dried seeds should be sprinkled with fungicidal drugs to prevent fungal attacks Similarly, treatment with gammaxine powder or *neem* pesticides make seeds resistant to insect attacks
(iv) Seed stores should be spacious and should have proper light arrangement.
(v) Details of seeds should be put on tags during storage. The information should have name of the species, collection site, date of collection and name of the person who collected it.

Maximum limit of germination capacity of important species is given in Table 15.4

Seed treatment

Amount of seeds required depends on

(i) *Species* Information regarding size of the seeds, germination capacity, number of seeds in 1 kg, etc., should be readily available Medium and large sized seeds are required in larger amounts
(ii) *Germination capacity/plant percentage*· Different species have different germination capacities For species with low germination capacity, large amounts of seeds are required
(iii) Objective of plantation and spacing
(iv) Purpose of requirement (distribution etc)

Quantity of seed needed for a bed can be roughly estimated by following formula

$$W + \frac{A \times D}{P \times N} \times 100$$

where:

W = Weight of seeds required (in grams)
A = Area of bed (in sq cm),
D = No. of plants required (per sq m.),
P = Plant of seed (%),
N = Number of seeds (per gm).

Table 15.4 *Maximum limit of germination capacity of important species*

S No	*Species*	*Maximum limit of germination capacity*
1	*Acacia catechu* (Khair)	1 Year
2	*Acacia nilotica* (Babool)	4 - 5 Years
3	*Ailanthus excelsa* (Maharukh)	4 Months
4	*Albizia lebbeck* (Kala siras)	1 - 2 Years
5	*Anogeissus pendula* (Kardhai)	1 Year
6	*Azadirachta indica* (Neem)	1 Week
7	*Albizia procera* (Safed siras)	5 Years
8	*Dalbergia sissoo* (Sissoo)	1 Year
9	*Hardwickia binata* (Anjan)	1 Year
10	*Holoptelia integrifolia* (Chirol)	1 Year
11	*Leucaena leucocephala* (Subabool)	5 Years
12	*Moringa oliefera* (Munga)	6 Months
13	*Pongamia pinnata* (Karanj)	1 Year
14	*Mangifera indica* (Aam)	2 Weeks
15	*Madhuca latifolia* (Mahua)	3 Months
16	*Terminalia arjuna* (Arjun)	1 Year
17	*Syzygium cumini* (Jamun)	3 Weeks
18	*Tectona grandis* (Sagone)	3 Years
19	*Shorea robusta* (Saal)	2 Weeks
20	*Eucalyptus spp* (Eucalyptus)	1 Year
21	*Gmelina arborea* (Khamar)	3 Months
22	*Anthocephalus cadamba* (Kadamb)	3 Months
23	*Dendrocalamus strictus* (Bamboo)	1 Year
24	*Prosospis juliflora*	5 Years
25	*Melia azadirach* (Bakayan)	2 Years
26	*Emblica officinalis* (Aonla)	2 Years
27	*Cassia siamea* (Kasodan)	3 Years

Seed weight and germination percentage of various species are given in Table 15 5

Table 15.5 *Seed weight, plant percentage and required pre-treatment of various species*

S No	*Species*	*Common name*	*Local name*	*Av no of seeds (per kg)*	*Germination (%)*
1	*Acacia cyanophylla*	Blue wattle	—	70,000	70-80
2	*Acacia dealbata*	Silver wattle	Wattle	75,000	70
3	*Acacia decurrens*	Green wattle	Wattle	70,000	40-80
4	*Acacia mearnsii*	Black wattle	—	71,000	80
5	*Acacia nilotica*	Babul	Babul	7,700	50-90
6	*Acacia catechu*	Khair	Khair	38,500	80
7	*Acacia senegal*	Gum arabic	—	12,500	60-70
8	*Acrocarpus fraxinifolius*	Shingle tree	—	30,000	—
9	*Adina cordifolia*	Haldu	Haldu	1,18,00,000	30-40
10	*Ailanthas excelsa*	Maharukh	Maharukh	25,000	40
11	*Albizzia falcata*	Batia	—	45 000	70-90
12	*Albizzia lebbeck*	Koko	Kala siris	8,000	Variable
13	*Albizia procera*	Siris	Safed siris	23,000	70
14	*Anacardium occidentale*	Cashew	Kaju	500	90-95
15	*Anogeissus latifolia*	—	Dhaura, bakli	1,20,000	20-30
16	*Anogeissus pendula*	—	Kardhai	1 50,000	20-30
17	*Anthocephalus cadamba*	Kadam	Kadamb	several hundred thousands	25
18	*Azadirachta indica*	Margosa	Neem	4,400	70-75
19	*Bischofia javanica*	Bishop wood	Paniala	90,000	Low
20	*Bombax ceiba*	Red cotton tree	Semul	28,000	50-70
21	*Butea monosperma*	Indian flame of forest	Dhak, palash	1,800	90
22	*Cassia fistula*	Indian laburnum	Amaltas	5,500	65
23	*Cassia siamea*	Yellow cassia	Cassia	35,000	75-80
24	*Casuarina cunninghamiana*	River oak	Casuarina	5,00,000	Variable
25	*Casuarina equisetifola*	Beef wood	Casuarina, sura	7,50,000	40-60
26	*Cedrela toona*	Burmaceder	Toon	3,50,000	60-80
27	*Cedrus deodara*	Deodar	Deodar	7,900	50-60
28	*Cinnamommum camphora*	Camphor tree	Karpur	9,000	Variable
29	*Cupressus torulosa*	Himalaya cypress	Surai	2,00,000	55-60
30	*Cupressus sempervirens*	Italian cypress	—	1,30,000	35-40
31	*Dalbergia latifolia*	Indian rosewood shisham	—	24,000 pods	50-60
32	*Dalbergia sissoo*	Sissoo	Sissoo	14,000 pods	80
33	*Dendrocalamus strictus*	Bamboo	Bans	55,500	60-80
34	*Erythrina variegata*	Coral tree	—	2 000 (also by stakes)	50-60
35	*Eucalyptus camaidulensis*	River red gum	Eucalyptus	4,00,000	Av 70,000 Plants per kg
36	*Eu citriodora*	Lemon scented gum	—"—	75,000	40-50

Contd

Table 15.5 *Contd*

37	*Eu globulus*	Blue gum	—"—	3,00,000	50
38	*Eu grandis*	Rose gum	—"—	2,50,00,000	25-28
39.	*Eu tereticornis*	Forest red gum or Mysore gum		3,65,000	90
40	*Gmelina arborea*	Gmelina	Gamhar, Shiwan	1,000 kernels	80-90
41	*Grevillea robusta*	Silver oak	—	1,05,000	Variable
42.	*Hardwickia binata*	Anjan	Anjan	4,800	90
43	*Holoptelia integrefolia*	—	Kanju	25,000	60-70
44	*Juglans regia*	Walnut	Akhrot	90,100	70
45	*Kydia calycina*	—	Pula	60,000	60-70
46	*Mangifera indica*	Mango	Aam	8-10	90
47	*Melia azedarach*	Persian lilac	Bakain	2,000 (fruit)	65
48	*Michelia champaca*	Champak	Champak	10,000	40-50
49	*Moringa oleifera*	Drumstick	—	900 (also stakes)	—
50	*Parkinsonia aculeata*	Jerusalem thron	—	12,500	85-90
51	*Picea smithiana*	West Himalayan spruce	Spruce	60,000	—
52	*Pinus kesia*	Khasi pine	—	50,000	80-95
53	*Pinus patula*	Patula pine	—	1,20,000	40-50
54	*Pinus radiata*	Montery pine	—	35,000	60
55	*Pinus roxburghii*	Chir pine	Chir	12,500	75-85
56	*Pinus wallichiana (Syn griffithii)*	Blue pine	Kail	15,500	70-85
57	*Pithocolobium dulce*	Madras thorn	—	6,000	60-65
58	*Platanus orientais*	—	Chinar	2,35,00	—
59	*Pongamia pinnata*	Indian beech	Karanj	1,500	75
60	*Prosopis juliflora*	Mesquite	—	25,000	90
61	*Prosopis specigera*	Jhad	Kikar, Khejri	28,600	45-65
62	*Pterocarpus marsupium*	—	Bija Bijasal	1,500	—
63	*Pterocarpus macroparpus*	Padauk	—	1,500	40
64	*Quercus incana*	Hoary oak	Banoak	500 (acorns)	60
65	*Quercus semicarpifolia*	—	Kharsu	200	65-75
66	*Quercus dilatata*	—	Moruoak	200	65-72
67	*Samanea saman*	Rain tree	—	5,500	90
68	*Santalum album*	Sandalwood	Chandan	8,500	75
69	*Shorea robusta*	Sal	Sal	500	60-70
70	*Spathodia companulata*	Bell tree	—	1,75,000	—
71	*Tamarindus indica*	Tamarind	Imly	800	60-70
72	*Tectona grandis*	Teak	Sag	2,500 (dry fruit)	60-80
73	*Terminalia arjuna*	Arjun	Arjun	200	60-80
74	*Terminalia bellerica*	Myrobalan	Baheda	500 (62 dry Baheda fruit)	85-95
75	*Terminalia chebula*	Black myrobalan	harra	150 (dry fruit)	40-50
76	*Terminalia tomentosa*	—	Ain, sain, madd	400 (fruit)	40-50
77	*Zizyphus mauritiana*	—	Ber	1,500	60-80

Seed treatment is an important activity before seed sowing. It improves the chances of seed germination. Seed treatment depends upon the hardness of seed coat Soft coated seeds, generally do not require seed treatment Even then such seeds may be treated by soaking for 24 hours in cold water Seed treatment processes for certain arid and semi-arid species are mentioned below in Table 15.6.

Table 15.6 *Recommended seed treatment processes for certain species suitable for arid and semi-arid areas*

S No	*Common name*	*Botanical name*	*Seed treatment*
1	Sitaphal	*Annona squamosa*	Soaking in cold water for 4 days
2	Palash	*Butea monosporma*	No treatment
3	Kaju	*Anacardium occiedentale*	—do—
4	Sarghwo	*Moringa oleifera*	—do—
5	Peltoforum	*Peltoforum ferrugineum*	Soaking in cold water for 24 hrs
6	Sissoo	*Dalbergia sissoo*	Direct sowing
7	Kashid	*Cassia siamea*	Direct sowing
8	Lemon	*Citrus quarantifolia*	Direct sowing
9	Gulmohar	*Dolonix regia*	Soaking in boiled water or soaking in con H_2SO_4 for 6 m then three times washing by clean water and keeping in wet gunny bags After 2-3 days sprouted seeds are sown in bags
10	Pink cassia	*Cassia javanica*	—do—
11	Goras imli	*Pithecellobium dulce*	Direct sowing
12	Karanj	*Pongamea pinnata*	Direct sowing
13	Nilgiri	*Eucalyptus spps*	Seeds are sown in sunken bed seedings are transplanted in bags after 2-3 pairs of leaves appear on stem
14	Bottle brush		—do—
15	Saru		—do—
16	Arjun (sodad)	*Terminalia arjuna*	Seeds are sown in beds Pre-germinated seeds are transplanted in bags
17	Badam	*Terminalia cutappa*	—do—
18	Siras	*Albizia lebbeck*	Direct sowing
19	Sevan	*Gmelina arboria*	Soaking in cold water for 48 hrs
20	Baheda	*Terminalia bellirica*	Soaking in cold water for 3-4 days
21	Ashitro	*Bauhinia purpurrea*	Soaking in hot water or soaking in Con H_2SO_4 for 5-6 minutes then three times washed by clean water Keep in wet gunny bags for 2-3 days Sprouted seeds are sown
22	Guava		Seeds are sown in raised beds After 2-3 pairs of leaves appear on stem they are transplanted in bags
23	Bengali baval	*Acacia auriculiformis*	Soaking in cold water for 24 hrs
24	Khajur	*Phonic dactylifera*	Soaking in cold water then keep in wet gunny bags After 4-5 days sprouted seeds are sown in bags Sprouted seeds are sown Seeds are sown in raised beds After 2-3 pairs of leaves appear on stem they are transplanted in bags

Contd

Table 15.6 *Contd*

25	Pomegranate	*Punica grunatum*	Direct sowing (viability very short)
26	Aritha		Soaking in cold water for 24 hrs
27	Amaltas	*Cassia fistula*	Soaking in con H_2SO_4 for 6 minutes Washed three times with clean water keep in wet gunny bags After 3-4 days sprouted seeds are sown in bags
28	Simako	*Bombax malabaricum*	Direct sowing.
29	Amla	*Emblica officinalis*	Hot water treatment Sprouted seeds are sown in bags
30	Khair	*Acacia catechu*	Direct sowing
31	Raintree	*Samania saman*	Soaking in cold water for 24 hrs
32	Mahuda	*Madhuca indica*	Direct sowing
33	Neem	*Azadirachta indica*	Direct sowing
34	Mangoes	*Mangifera indica*	Sown in beds (viability very short) Germinated mangoes are transplanted in bags
35	Ram baval	*Parkinsonia aculeata*	Soaked in hot water for 10 minutes then keep in gunny bags for 24 hrs
36	Parijatak	*Nyctanthes arbortristis*	Direct sowing
37	Jamun	*Syzygium cumini*	Direct sowing after seed collection
38	Ber	*Zizyphus jujuba*	Soaked in cold water for 2-3 days
39	Buch	*Millingtonia hortensis*	Branch cuttings
40	Bamboo	*Bambusa spp*	Seeds are sown in raised beds Rhizomes are transplanted in bags
41	Harde	*Terminalia chebula*	Soaked in cold water for 2 days Remove upper seedcoat Keep in wet gunny bags for 4 days
42	Khati imli	*Tamarindus indica*	Soaked in cold water for 24 hrs
43	Gunda	*Cordia dichotoma*	Direct sowing
44	Subabul	*Leucaena leucocephala*	Soaked in hot water for 10 minutes Keep in cold water over night
45	Siras (white)	*Albizia procera*	Direct sowing

Leguminous, cosurinacious, cupilliferous families have nitrogen fixing nodules Rhizobium is more effective when soil is fertile, has sufficient aeration and moisture Excess water may harm the rhizobium Light helps in nitrogen fixation and nodule formation Excessive acidity in soil (pH 4 5) kills rhizobium Phosphorus mixture helps in nitrogen fixation Seeds should be actively and properly mixed with rhizobium After drying in shade, such seeds should be sown Lime or rock phosphate cover on seed coat gives better results

Direct seed sowing has proved to be a very effective method in semi-arid and sub-humid areas of Jhabua A mass scale plantation exercise through seed sowing on contour trenches, *nalla* bunds, common wastelands in the year 1996-97 has given fantastic results Plants percentage and survival of the seedlings of certain species has indicated that direct sowing is a better option in arid conditions Lakhs of *Jatropha curcuns* (Ratanjot), *Prosopis juliflora* (Vilayati babool), *Acacia catechu* (Khair), *Azadiracta indica* (Neem), *Pithecelobium dulce* (Jungle jalebi), etc, saplings germinated from seed sowing They have produced biomass on susceptible and vulnerable terrains

Nursery raising

Selection of nursery site

It is important to establish nursery on slightly sloping fertile land. Growth of saplings in nursery require continuous and sufficient source of water supply. So, the proposed nursery site should be close to perennial source of water. Natural or artificial fencing is needed for protection from stray cattle and others Saplings need protection from direct sunlight for initial period So fast growing trees in the nursery should be grown. Shadow from such plants or trees would protect young seedlings from direct sunlight. If nursery is close to a road, then transportation of seedlings to plantation site would be easy. As far as possible, nursery should be close to plantation site. In short, the following criteria should be kept in mind for selection of site for raising nursery:

(i) slightly sloping, fertile land,
(ii) proximity to permanent source of water for irrigation,
(iii) natural or artificial fencing,
(iv) shadow trees in proximity,
(v) proximity to road for transportation, and
(vi) closeness to plantation site.

Nursery tools and implements

These include

1 diesel/electric motor and pump
2 pipe for movement of water
3 hammer
4 files
5 plier
6 punch
7 sandpaper*
8 box*
9 brick/cement bags*
10 wheel barrow*
11 seed germination tray*
12 table and chair*
13 wiremesh*
14 shovel
15 watering cans
16 pans *(gamalas)*
17 harrow*
18 earthen pots
19 budding and grafting knife*
20 transplanting travel*
21 garden scissors
22 sickle
23 sekater*
24 pruning handsaw*

25. axes with handles
26. weighing balance*
27. sprinkler/sprayer*
28. aging iron*
29. pick axes
30. crowbars*
31. bill hooks*
32. khurpis
33. pruning knife*
34. secaters*
35. pruning saw*
36. crosscut saw*
37. ropes, strings, threads, needles
38. measuring tape
39. paint(black, white,green,red, yellow)*
40. stapler and staples*
41. chalk
42. pencil, pen, paper,
43 magnifying lens*
44 paint brushes*
45 insecticide, weedicide
46 packets of seeds
47 polythene packets

(*) Not needed in household and/or SHG nurseries

Size of nursery

It is important to estimate the number of seedlings to be raised in a nursery. The nursery size can be accordingly worked out. Three levels of nurseries for watershed areas have been mentioned earlier The size of the polythene container to be used should also be taken into account. For example, with the 25x17 cm polythene bags of 150 gauge, usually 1 ha nursery can support about 2,00,000 seedlings With smaller-sized bags, more seedlings per ha would be possible But there is the likelihood of damage of roots in smaller bags during shifting in the nursery and to the field

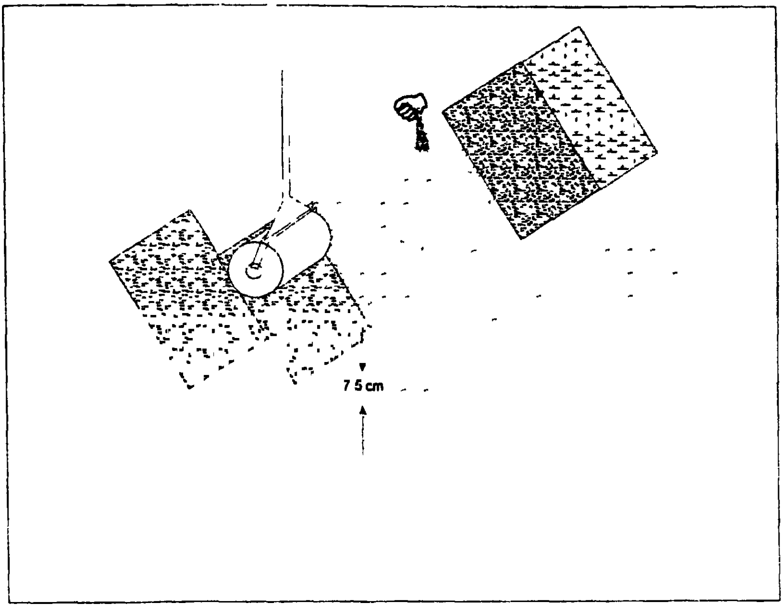
Preparation of site

The nursery site should be cleaned in preceding winter When first laid out the whole nursery should be thoroughly ploughed to depth of 45 cm and all stumps, roots, deeper grass roots, and stones should be removed This should be done at the end of rainy season and should be kept fallow till the following season Clods and lumps should be then broken and whole area smoothened In very light soil, deep working should not be done Site which needs draining out in the beginning should not be selected (Figure 15.1)

Soil preparation

Nursery soil should have a mixture of soil, sand and manure in the proportion of 6:3 1 respectively Expensive mineral fertilisers, are used sparingly Cheaper manures like leaf

Figure 15.1 *Preparation of nursery bed*



litter, animal dung and wood ash are also easier to obtain and equally effective It is usually spread over the beds, 5-10 cm thick, turned in with soil and worked up after rains Animal dung needs careful rotting in heaps, under cover and takes a year to mature. Manure should be free of grubs, white ants, etc , when used.

A cheap nursery manure is made by piling alternate layers, 15-20 cm thick of soil, dung and vegetable matter and covered with a layer of soil about 20 cm thick and left for a year. When mixed with wood ash this makes an excellent manure.

Preparation of seed germination beds

Seed beds are prepared just before sowing Standard beds are of 1x10 m size, rectangular in shape, raised 15 cm above ground They are sunken type (15cm deep) in arid areas and hot places. Beds are given side supports of bamboos, twigs, sawmill wastes or even bricks Longer side of the bed should normally be towards hottest sun or wind. In India, beds should normally have longer sides running east-west. Surface of the bed should be absolutely flat or convex. There should be sufficient space for keeping such large number of bags with proper shade arrangement. Normally upto 2500 bags are arranged in one transplant bed, preferably sunken Sapling from one bed in nursery should be sufficient for plantation in 1 ha. Germination boxes/pans may be used for testing germination percent of delicate seeds. Raised platforms are sometimes used for seed germination.

Method of sowing

The method of sowing is cost effective, saves times and is less cumbersome. For sowing, nursery raising is not required and the roots are not disturbed. But, on the other hand, due to wastage of seeds and low rate of germination large quantity of seeds are required. Also, the seeds may be damaged by birds and extensive weeding operation has to be undertaken

Large seeds (e.g , teak) should be sown individually in drills running across the width of the bed. Drills are conveniently laid by pressing down a 'drilling board' on the prepared bed. This is a board of the width of the bed and of a convenient length to mark out say drills, of the required width, thickness and shape. The drills are evenly spaced, the space depending on the species. Small seed may be drill-sown in the above manner or broadcast over the seed beds. The later procedure may be followed in cases where seedlings are to be pricked out into pots as in the case of casuarina and eucalyptus. Where germination is irregular, pre-germinated seeds may be sown in the drills. This is required in cases of large-sized seeds or fruits. These are almost invariably treated before sowing. Seeds sown should be covered to a proper depth. This may be done by raking over the soil in the case of large seeds. In the case of small seeds, they should be covered by sand, fine sub-soil or leaf mould. The depth of the cover should be to a minimum diameter of the seed Some seeds like cashew, khair, etc , are better sown directly into the container, without resorting to transplanting

Time of sowing

Seeds of different species have to be sown in different months Seeds of most species, where potted plants are used for planting, are sown between January and March, and those where stumps are required, between May and June When sowing is done in hot weather, the top layer of the seed bed should be thoroughly soaked before sowing is carried out Surface soil is kept uniformly moist till germination starts.

Transportation of seedlings

For many species modern nursery practices recommend planting the seedlings at site with ball of earth, wrapped around the rootstock The procedure of transplanting involves transferring of the germinated seedling from primary bed to a container, packed with good mixture of earth The seedling establishes itself well in the polythene bag, nurtured by fertile soil and moisture Later at appropriate time, the seedlings are transported to the planting site and they are planted in the planting pits with the ball of earth undisturbed, after removing the polythene film The container generally used are the polythene bags which are manufactured from polythene granules They are cylindrical and are closed on one side

The process of transferring the seedling from the primary germination bed to a second temporary home (in case of polythene container, which are also called polypots or polybags) is termed *transplanting* Special care is necessary in nurturing the plants in the containers Nutritious soil with moisture retention capability is used in the containers Soil mixture should contain farm yard manure and some sand in case of clayey soil The polybags so made are stacked side by side, generally. in the same-sized beds as the primary ones so that weeding, watering and aftercare is convenient

Each seedling is carefully separated from its neighbours If its roots are crushed or are too long, they are trimmed The seedling then is placed in the centre of the polybag, already filled with soil and kept moist for some period The root portion upto the collar is gently placed in stick-made-hole to size. The soil is then lightly heaped around the seedling to cover the vacant spaces in the hole and then watered The seedlings thus transplanted into the polybags are left under shade for a day for recovery Thereafter, they are arranged in the open or under shade according to the species and the local conditions. Some species like *Eucalyptus citiodora* do not stand transplanting The seed may be directly sown in polybags When seed viability is suspect and germination is poor, the primary bed stage is helpful.

Use of fertilisers

An ideal fertiliser should be cheap per unit of sapling, give high growth response, be easy and safe in handling in the field, keep physical and commercial properties intact during storage, maintain fertility and physical-chemical properties of soil at optimum levels.

(a) *Commercial fertilisers* Even though there are different kinds of fertilisers available, it is best to use FYM, forest litter, leaf mould, ash, etc , which are cheap, easy to apply and equally beneficial

(i) *Nitrogen fertilisers*:

(16% N) Sodium nitrate ($NANO_3$) Alkaline Good for broad leaves

(16%N) Calcium nitrate, Ca $(NO_3)_2$ Good for acid soils deficient in calcium

(35% N) Ammonium nitrate (NH_4NO_3) Good for both broadleaves and conifers.

(20% N) Ammonium sulphate $(NH_4)_2$ SO_4 Useful in high soil acidity

(42% N) Uramon $(NH_2)CO$ Neutral to acid reaction

(2-15% N) Organic nitrogen fertilisers. These include dried weed, bonemeal, cotton-seed meal, activated sewage sludge, garbage tobacco stem, etc They are rather costly for nursery

(ii) *Phosphate fertilisers*

(33% P_2O_5) Rock phosphate· $Ca_3(PO_4)_2$, CaF_2,70% tricalcium phosphate Good for broadcast and peat compost

(14-25% P_2O_{55}) Super phosphate CaH_4 $(PO_4)_2$ Good for calcium deficient soils

(40-50% P_2O_5) Double super phosphate· CaH_4 $(PO)_2$ Good for all soils except the calcium deficient.

(iii) *Potassium fertilisers*

Potassium chloride(KCL) 50-60% K_2O Careful application as it is toxic

Potassium sulphate K_2SO_4 (48-60% K_2O)

Manure salts Carnalite, Kainite, Sylvinite(9-16% K_2O)

Wood ash 2-8% K_2O, some P_2O_5, and CaO

(iv) *Composite fertilisers*

Potassium nitrate KNO_3, (13% N, 45% K_2O) Used in liquid treatment

Mono-ammonium sulphate $NH_4H_2PO_4$,(11%N, 48% P_2O_5) Used in liquid treatment

Diammonium sulphate $(NH_4)_2$ HPO_4 (21% N, 53% P_2O_5)

Mixed fertilisers In which N, P, K are in different proportions, viz , (3-9-8), (3-12-12), (6-6-18), (0-10-20), (0-9-17), etc

(v) *Lime* Burnt or slaked lime is dangerous A green manure crop or transplanted stock should be therefore grown between lime application and seed sowing

(b) *Manures* These are products of plant or animal origin having essential nutrients for plant growth

(i) *Green manure*: Raised as crops and then chopped and ploughed back into the soil to decompose. Excellent green manures are obtained from *Sesbania spp*, *Crotolaria juncea*, *Glyricidia maculata*, *Pongamaia pinnata*, *Calotropis gigantia*, *Tephrosia purpurea*, *Cassia tora*, *Peltroforum pterocarpum* and *Leucaena leucocephala*

(ii) *Farmyard manure*: Properly decomposed dung, urine of animals and vegetable waste matter.

(iii) *Compost*: Decomposed plant residues.
Night soil, sewage.
Oil cakes.
Bone meal (good for acid soils)

(iv) *Others*: Fish meal, dried blood, slaughter house waste, tannery refuse, husk, poultry-shed soil, etc

Fertilisers are applied through broadcasting, localised placement or spraying. Basal dressing is applied before sowing the seeds. Top dressing is applied to grown up seedlings (a) In case of mobile nutrient salts (e g, nitrate, chloride, sulphate) fertiliser should be applied at the time of peak requirements. (b) In case of immobile nutrient salts (e.g, calcium, phosphorous, ammonium, potassium, magnesium, iron, zinc, manganese and molybdenum) fertiliser should be applied as a basal dressing at the time of sowing Fertiliser should be applied 3 or 4 times in a year instead of once-in-whole-lot Fertiliser should not be applied if heavy rains are expected Fertiliser should not be applied in dry soils. Light irrigation after application of fertiliser is good

Irrigation

(a) *Flooding*· The whole bed is flooded. Flooding is easier in case of sunken beds Flooding should not be used in case of very small seeds The main objection to this method is that it leaves a fine sediment which forms a crust over the bed The seeds should be sown in lines when flooding is adopted for watering When seeds take more than three weeks to germinate, flooding should not be used as it gives more weed growth.

(b) *Percolation* Water percolates from furrows, which are flooded In this case it should be seen that no point of bed is more than 30 cm away from the furrow. The method uses less water

(c) *Sprinkling*. Sprinkling of water from cans is the recommended method for small seeds Rotating sprinklers are also available, which can imitate rainfall, but are very expensive

(d) *Individual*· Plants are watered by keeping a small (1 litre) clay pot with a small hole with a wick Water is applied at the base of plant touching roots. This is done for a short period, usually during peak summer temperatures to help the plant to stand the heat and water loss (Plate 41)

Weeding and soil working

From the moment the young plants appear, till they are finally transplanted, they should be kept absolutely clear of weeds Soil is kept well worked up and not just scratched on surface From sowing to break of rains, weeding and soil working are the most important exercises than even watering

As soon as the beds are full of seedlings, they should be thinned out and kept so to

Plate 41 *Sprinkling of water from cans is recommended in SHG nurseries Irrigation should be curtailed, atleast two weeks before planting out, to toughen the plants*

avoid competition This is not necessary when seedlings are picked out in beds or in polythene bags Weeding, soil working and thinning are very important and time bound operations, and any delay will turn a successful seed bed into a failure.

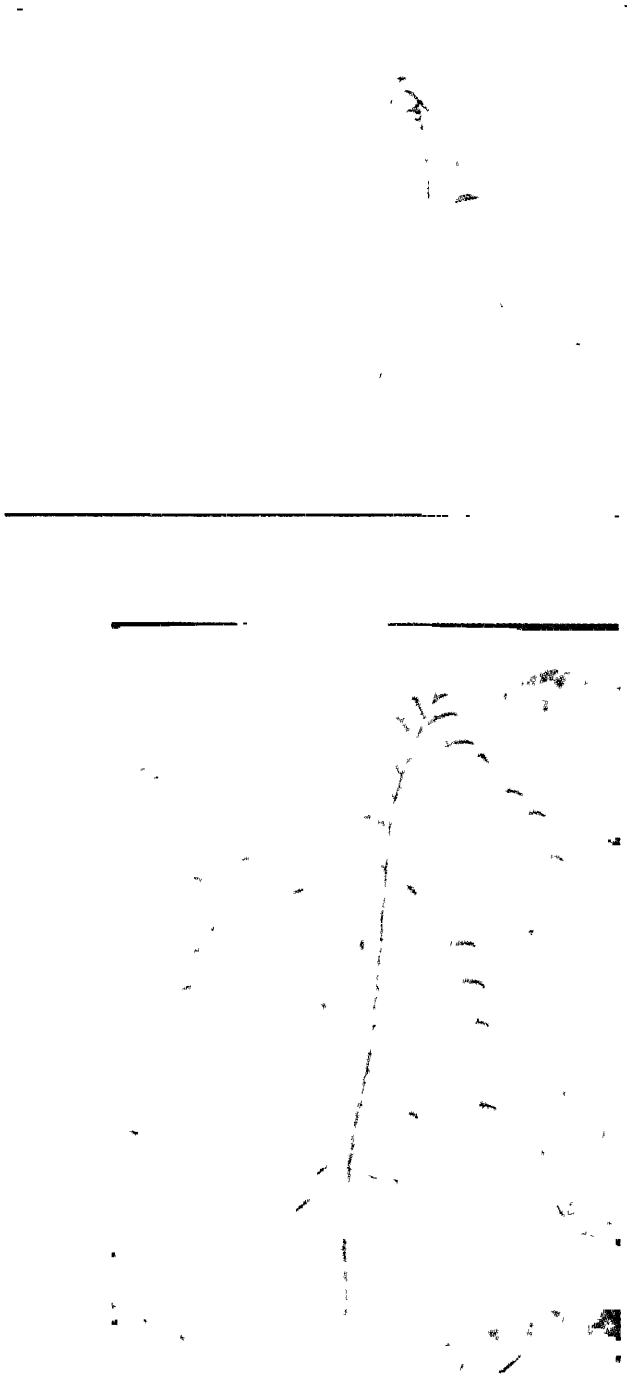
When shade is provided, it should be removed on cloudy days and during, early rains to harden the plants. At the end of August no shade is necessary for most species Shade should be gradually thinned and removed, atleast two weeks before planting out, along with reduction in watering regime to toughen the plants.

Removing the plants from nursery for plantation

A trench deep enough to get whole root and entire transplant, about 45 cm deep, should be dug at the end of the bed Earth is dug out into this to avoid injury to the plants Bed should be thoroughly wet before digging them out. Plants should be removed in the afternoon, carted in late evening and planted early in the next morning At no time should plants be exposed to sun. When entire transplant is taken out, best size is when their root is 15-22 cm long and stem has two or three leaves. It is better to transport such seedlings packed with ball of earth and transported in baskets or gunny sacks tied around a bundle and kept moist. Never wash or remove earth sticking with the roots The leaves should be sniffed off before planting

When stock is ready in polythene bags, it is thoroughly watered 24 hours before transport They are transported with bags, but bags are torn off before planting without disturbing the ball of earth (see Plate 42 a, b)

Plate 42 (a, b) *Saplings should be removed from nursery beds when they attain suitable height*



Planting rules and other activities

Planting in the field should be carried out in as short a time as possible, and as close to the start of rains as feasible. This is necessary as the growing season is very short and it is essential to give as long as possible a time to develop roots before the growth ceases in October. Planting should be done rapidly A fortnight after rains is the latest date any planting should be done. Sufficient labour force and transport must be arranged to complete the work in time

Planting rules

(1) Bigger plants should be used in dry soils than in wet soils
(2) After the soil has set, the collar of the seedling/root shoot cutting should be in the same position with reference to the soil as it was in the nursery If the collar is above, plants are likely to die from exposure of roots to the sun If too deep, new root development is superficial
(3) Roots should not be bent or cowed in the hole or pit They should lie easily
(4) In wet soils mound planting is advisable Soil under the mound should be picked at least 15 cm deep before making the mound.
(5) In very dry, well drained soils, the plants may be planted in pits However, making pits in other soils may be detrimental, for the pit then becomes a non-aerated puddle
(6) Best soil only should be placed in contact with the roots On poor soils, the surface soils should go first into the pit or hole Litter and organic matter should not be in contact with the roots
(7) Soil must be thoroughly packed around the plant
(8) After planting, weeding and soil working during first rains, help encourage plant growth
(9) Weeding must be done carefully In clayey soil, if it is not pulverised and aerated before planting, excessive moisture will turn it into a compact mud Weeding done at such a time, will be more harmful than useful Weeding should be only done when the soil is sufficiently dry to shake away freely from the weed roots
(10) Soil working should be done along with weeding The working instrument should go well below the surface pulverising superficial soil layers. Soil working should be done when soil is sufficiently moist and not wet mud Moisture evaporates more quickly from packed smooth surface than when surface soil is loose Soil working breaks the capillary movement of water and prevent evaporation
(11) Soil working should not be done when there is long, hot drought and also during the monsoon downpour

Stump planting

Root-shoot cutting planting. They are made from healthy seedlings, which are about a year old. Root-shoot cutting of a seedling which is 2 cm or more (thick as finger or thumb), with 15-20 cm (9 inches) root length and 2 5 to 4 cm (1 1 inches) shoot position with clean slanting cut is preferred Experts are of the opinion that root-shoot ratio should be 9 1 Other roots are pruned off They are then packed in bundles of 100 each, in leaf or gunny sack. Root-shoots are planted in slightly slanting holes sufficiently deep to allow comfortable placing of roots Atleast 1-2 cm of shoot part is allowed above ground Soil around the root-shoot is then well packed. Not much time should be wasted in sowing/ planting root-shoot after its preparation. They should preferably be planted within twenty-four hours. In case of delay, they should be kept in soaked and muddy gunny bags.

Certain species like *Acacia catechu* (Khair), *Ailanthus excelsa* (Maharukh), *Albizza lebbek* (Kalasiras), *Anacardium occidentale* (Anaar), *Bauhinia racemosa* (Kanchan), *Bauhinia variegata* (Kachnar), *Dalbergia sissoo* (Sisham), *Dalbergia latifolia* (Kala siras), *Holoptlea integrifolia* (Churd), *Madhuca latifolia,* (Mahua), *Melia azedarach* (Bakayan), *Pterocarpus marsupium* (Beeja), *Shorea robusta* (Saal), *Syzygium cimini* (Jamun), *Terminalia arjuna* (Arjun), etc., can be stump planted.

Cutting

Branch cutting should contain 3-4 buds on it. The cutting is done immediately below the lowermost bud. Those may be placed in wet sand or sawdust for around four weeks. They may be planted having one bud put above the ground level in nursery beds, 30 cm apart, in rows The distance between rows should be 60-75 cm. One year old plants from the nursery can then be used as seedlings for plantation. Species like *Punica granatum* (Anaar), *Morus alba* (Shatoot), *Moringa oleifera* (Drumstick), *Grewia asiata* (Phalsa) are commonly planted by cutting. Others like *Ailanthus excelsa,* (Maharukh), *Dalbergia sissoo* (Sisham), *Erythrina suberosa* (Gandha plash), *Erythrina variegata, Ficus auriculata, Lannea coromandelica* (Godal), *Melia azedarach* (Bakayan), *Morus senata, Populus indica, Pithecolobium dulce* (Madras thorn), *Psidium guajava* (Amrood), *Salix alba*, etc., may also be planted from cuttings It is not necessary to place cutting in nursery for a year These methods are very cost effective and simple to implement. Promotion of such methods may be taken up in watershed areas.

Root cutting

Plant species with fleshy roots like *Emblica officinalis* (Aonla) can be planted with root cuttings. The roots of such species develop small whitish knobs of shoots in early spring. Approximately 10 cm roots are cut and planted 2.5 cm deep keeping a distance of 15-20 cm under partial shade in sandy soils. They need frequent watering for 4-5 months. Seedlings, so prepared, may be planted in autumn Select species like *Acacia mearnsii* (Black wattle), *Azadirachta indica* (Neem), *Dalbergia sissoo* (Shisham), *Erythrina suberosa, Melia azedarach* (Bakayan), *Santalum album* (Sandalwood), etc , may be planted with root cuttings

Layering

Certain plant species start rooting when the shoots come in contact with soil Such trees can easily be propogated by layering The lower part of the shoots of the trees may be incised below upto 2-5 cm and they are pegged down in the soil. Nutrient rich soil along with 50% sand may be added in the pegged area Species like *Grewia optiva, Punica granatum, Tamarindus indica.* In Jhabua, *Ipomia* (Beshram) shoots have been used to stabilise and to create resistance to runoff on *nalla* bunds on fast flowing *nallahs* on steep slopes. It also helps in trapping eroded soil. Likewise, *Bougainvillea* species have been used as soil binders on steep slopes and degraded land especially in Chhindwara district of Madhya Pradesh This method is also very cost-effective

Budding

It is performed on the seedlings (especially root stocks) after removing the vegetative portions and cutting a T-shaped cut in the bark The bud of the desired plant is inserted in the cut part of the root stock This portion is then firmly tied with polythene to squeeze out all the air inside The bud starts growing after protection, nursing and watering From six months onwards the budded plants become ready for planting. Regular and indigenous trees of *Zizyphus nummularia* can be improved with more productive and pest-resistant improved plant buds In Jhabua, a major excercise of budding 1 76 lakhs Ber trees *(Zizyphus mauritiana)* was performed with the help of village volunteers in watershed areas. Other species on which these operations could be performed are *Emblica officinalis* (Aonla), *Morus alba* (Mulberry rose), etc

Plantation in watershed areas

Time of planting

Usually, most of the planting is done during the monsoon, especially after a good soaking rain, though pre-monsoon or winter plantings can also be taken up provided irrigation facilities are available As a rule, all plantings should be completed within a period of 3-4 days after a good soaking rain Winter plantings may be successful in areas which get winter rain like states of Kerala, Tamil Nadu, etc *Deodar, Acer, Prunus*, etc , may be planted in winter In good years, most planted saplings will survive, while in marginal years, mortality is very high The management of such marginal years is a crucial factor This becomes more important when the period or duration of rainfall is short High labour rates in the agricultural season may require new employment avenues in lean season Labour-intensive works should be taken up in off-season/lean-season

Site preparation

(a) *Pits* Site preparation for plantation should be completed in advance (see Figure 15 2) Numerous kinds of pits are possible

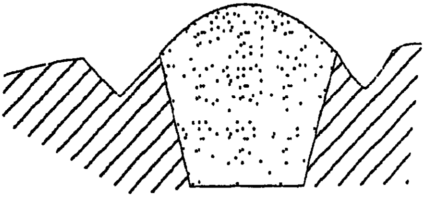
(i) *Ordinary pit* (Clayey and saline/alkaline soil in all rainfall classes) It is a pit dug up with high crest and a deep water storage ring, away from the highest point of the mound Such '*thalas*' minimise waterlogging and concentration of salts near the seedling In black cotton soils, it may be desirable to mix some coarse organic mulch like grasses, leaves and small twigs with soil in the pit to improve the soil structure, water permeability, eliminate or reduce cracking and reduce evaporation losses This type of pit is also suitable for sandy soils, whose water retention capacity could be improved by incorporating partly decayed organic mulching material.

(ii) *Saucer pit* This kind of pit is suitable for all loamy types of soils in almost all rainfall classes. The crescent trench is essential on sloping terrain

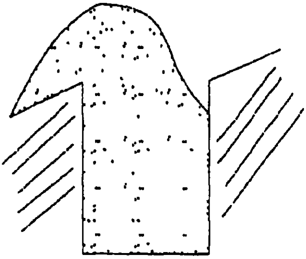
(iii) *Ring pit* The crest need not be very high, because deep planting may be necessary in order to place the main mass of roots about 30 cm below the surface, to utilise moisture accumulated in sandy soils The ring trench will allow water to infiltrate near the planting site, and thus improve its moisture status.

(b) *Ridge-ditches* These are partly filled-in trenches, and are suitable for sowing or planting on sloping ground

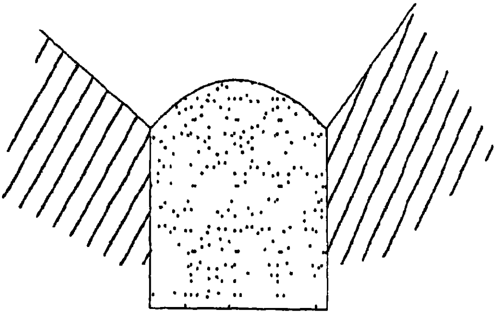
Figure 15.2 *Soil working methods (pits, trenches, ridges mounds)*



(A) Ordinary Pit



(B) Small Ridge Ditch



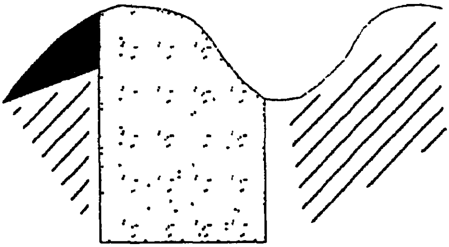
(C) Saucer Pit

(i) *Small ridge-ditch:* This is commonly used ridge-ditch pattern It is suitable for areas toward the more moist part of the dry zone with a relatively large number of rainy days and for loamy soils.

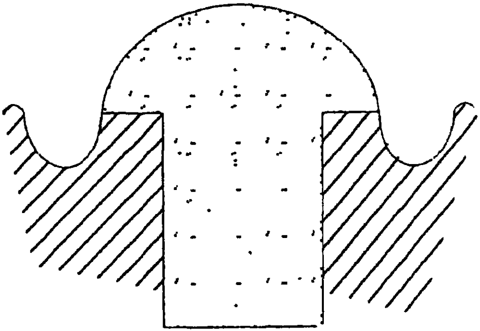
(ii) *Large ridge-ditch*: This is a typical pattern suitable for low rainfall and deep soil conditions, if the soil is sandy and the rainfall rather low and the number of rainy days is not small This pattern will trap a large amount of moisture in the worked-up soil It is also suitable for low and ill-distributed rainfall areas with non-sandy soils

(iii) *Shallow ridge-ditch* This is recommended for slopes from which most of the topsoil has been washed away, and the surface consists of loose gravel or *murram* of shallow

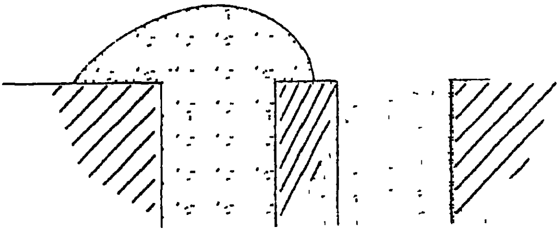
Figure 15.2 *Contd*



(D) Ridge Ditch



(E) Ring Pit

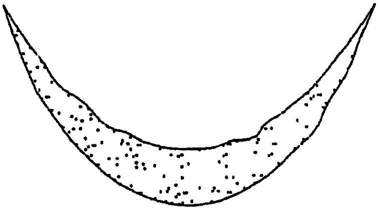


(F)

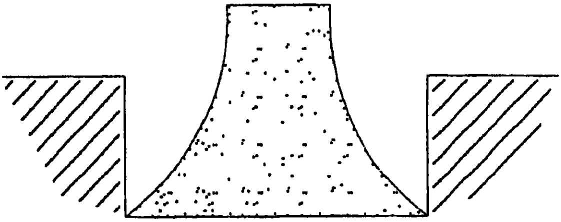
depth, where the soil is extremely granular and has low moisture retentive capacity As hard rock is encountered relatively near the surface, volume of worked-up soil is easily obtained by doing wider rather than deeper excavation. As the excavated material is stony and gritty, it is advisable to do some sorting of this, and to put the larger pieces at the bottom of the trench and at the toe of the ridge on the lower side of the slope

(iv) *Sloped ridge-ditch*: This method is suitable where the surface soil is shallow and the sub-soil is also coarse and gritty, and fine clay with crusting properties is present in appreciable amount This method stores enough moisture and does not cause water-

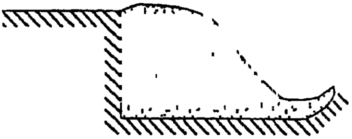
Figure 15.2 *Contd.*



(G) Crescent Pit



(H) Inclined Trench Mound



(I) Wurli

logging near the ridge. Slanting rather than vertical sides are adopted on ditches This pattern keeps the main mass of water away from the sowing or planting lines and thereby reduces the damage from waterlogging.

(v) *Half slanting ridge-ditch.* This method is recommended for areas where the rainfall is low and rather ill-distributed, and the soil is friable. This pattern may be adopted to increase the soil-water collecting space

(vi) *Shallow slanting ridge-ditch:* Suitable for shallow, rather clayey, soils with good rainfall.

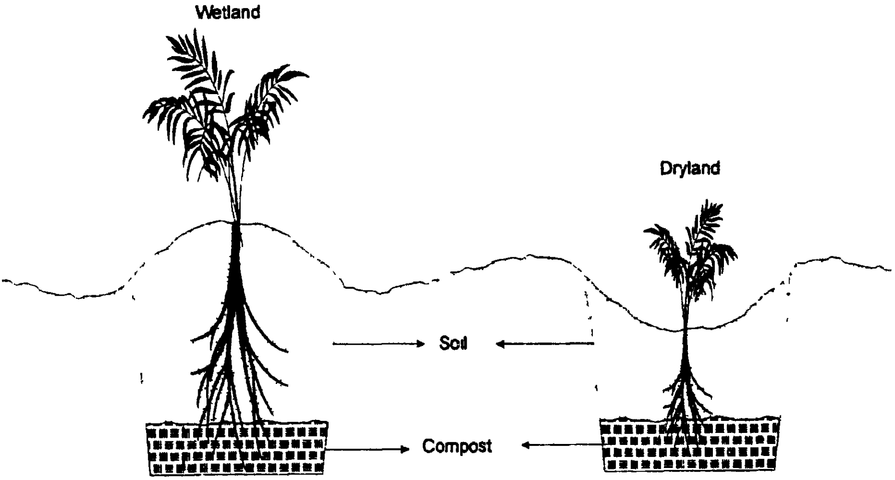
(c) *Shelved trench* Some soils in the peninsular region, derived from granitic or basaltic rocks, contain a proportion of very fine tenacious clay, dispersed in a matrix of fine to coarse-grained *murram*. The sides and bottom, the slopes and top of the ridge develop a hard crust after the first showers. For such an area a shelved trench with sowing or planting at the original ground level or a little above it, may prove superior to the conventional trench A variation of this is the deep filled shelved trench which is suitable for areas with low to high rainfall received in a small number of rainy days in the form of heavy or torrential showers, requiring a relatively large storage capacity.

(d) *Double trench*: In case of very stony and sloping terrain, which contains only a small amount of soil in the inter-spaces of large and small pieces of stones and in the cracks and crevices of the partly disintegrated rock, the water holding capacity is extremely small and the surface runoff and sub-surface drainage is very high. Planting at the top of the ridge or deep into the soil mass have higher survival rates.

(e) *Trench ridge*· This technique is suitable for salt impregnated soils. It provides for efficient leaching of salt from the seed bed and minimises damage from waterlogging. The trench is shallow but deep enough to cope with frequent showers, and the deepest part of the trench is well away from the ridge, to avoid waterlogging as well as to facilitate desalinisation. A deep trench ridge is suitable to soil with a high salt content, where the rainfall is scanty and is received in a few violent storms.

(f) *Trench mound*: This method is suitable for ensuring success of plantings and sowings under conditions of low, erratic and badly distributed rainfall Whereas the double-trench or trench-pit is suitable for moderate to steep sloping ground, the trench mounds are adapted to flat or gently sloping areas

Figure 15.3 *Tree planting*



(i) *Inclined trench mounds*: If the area has a gentle slope, it is preferable to have the two arms of the trench, a little off the contour in order to allow the water to accumulate near the mound The surplus earth should be formed into a low sloping ridge on the downward side.

(ii) *Straight trench mound.* If the slope is not uniform, gentle straight trench mounds may be constructed.

Suitable plant species should be selected for pit patterns based on ephadic and climatic conditions Various types of pitting and trenching on different soil types and rainfall classes are given in Table 15.7 (also see Figure 15 3).

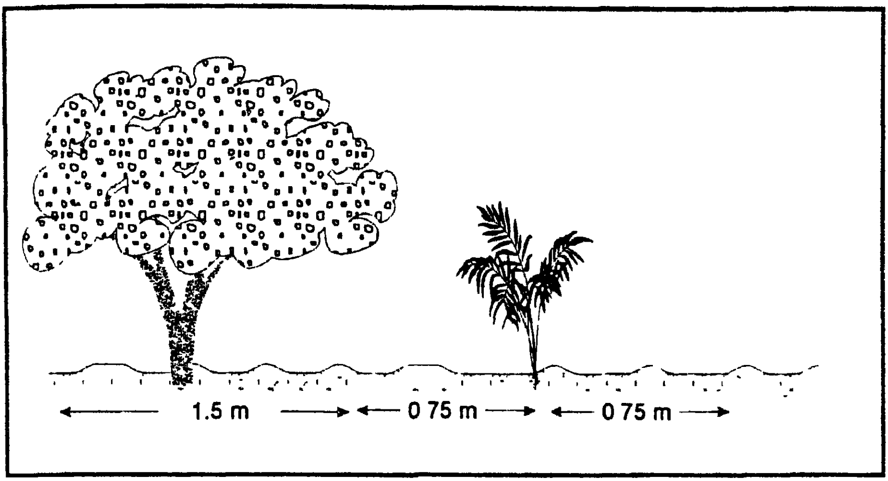
Table 15.7 *Suitable pits and trenches for different soil types and rainfall classes*

S No	*Type of pitting/trenching*	*Soil type*	*Rainfall class*
A	*Flat lands*		
1	Ordinary pit	Clayey	All
2	Saucer pit	Salt affected, loams	All
3	Ring pit	Sandy soils	All
B	*Sloppy lands*		
4	Small ridge-ditch	Sloppy	Moist part of dry zone
5	Large ridge-ditch	Sloppy deep	Low
6	Shallow ridge-ditch	Eroded sloppy	All
7	Sloped ridge-ditch	Shallow soils with coarse sub-soil with fine clay	High
8	Half slanting ridge-ditch	Friable	Low
9	Shallow slanting ridge-ditch	Shallow clayey	High
C	*Heavy soils*		
10	Shelved trench	Fine soil interspersed with murram	Medium to high
11	Deep filled shelved trench	Sandy, gravely salt affected	All
D	*Stony land*		
12	Double trench	Stony sloppy	All
E	*Salt affected soil*		
13	Shallow trench-ridge	Alkaline	All
14	Deep trench-ridge	saline	Low
F	*Low rainfall zone*		
15	Inclined trench-mound	Gentle slope	Low
16	Straight trench-mound	Not uniform slope	Low

Spacement in plantation

Every species has an optimal spacing This spacing depends on numerous factors Wider spacing is recommended for fast growing species For species with branching habits close spacing is recommended to induce natural pruning Closer spacing is used in the denuded areas for site protection and in the areas prone to heavy weed infestation. Closer spacing is also adopted for producing close-grained timber for greater mechanical strength Taller and light-demander tree species require wide spacing. Wider spacing is also recommended when three tiers of vegetation providing fuel, fodder and timber is envisaged In arid and semi-arid areas, the competition for moisture necessitates the plantations with wider spacings (Figure 15 4)

Figure 15.4 *Tree spacing*



Number of plants per hectare for regular spacing in·

(i) Square planting.

$$\frac{10{,}000}{\text{Square of planting distance (in m)}}$$

(ii) Rectangular planting:

$$\frac{10{,}000}{\text{Spacing in line (in m)} \times \text{spacing between lines (in m)}}$$

Spacing of plants and number of plants per hectare in square and rectangular planting are illustrated in Table 15 8

Maintenance and aftercare

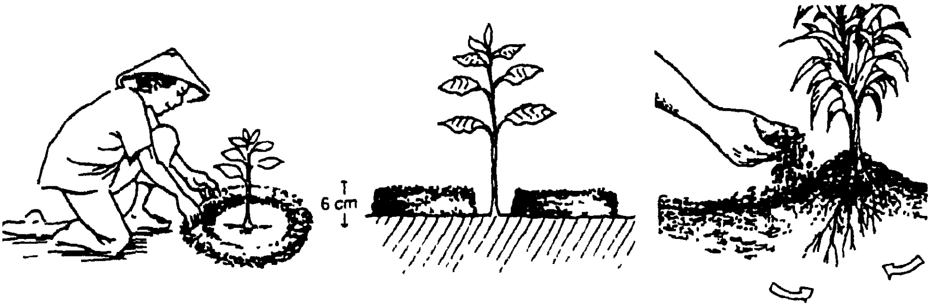
All plant species require maintenance and aftercare for a long duration after planting. Plants in arid and semi-arid conditions demand a longer duration of maintenance and aftercare Aftercare may be needed even for a period of four or five years, before the plants can

Table 15.8 *Spacing of plants and number of plants per hectare in square and rectangular planting*

Square planting spacing (in metres)	*No of plants (per hectare)*	*Rectangular planting (in metres)*	*No of plants (per hectare)*
1*1	10,000	1*2	5,000
1 5*1 5	4,444	1*3	3,334
2*2	2,500	1*4	2,500
2 5*2 5	1,600	2*3	1,667
3*3	1,111	2*4	1,250
3 5*3 5	816	2*5	1,000
4*4	625	3*4	834
4 5*4 5	494	3*5	667
5*5	400	4*5	500
5 5*5 5	331	4*6	417
6*6	278	5*6	313
6 5*6 5	237	5*7	286
7*7	204	5*8	250
7 5*7 5	178	5*9	222
8*8	156	5*10	200
8 5*8 5	138	5*15	133
9*9	123	5*20	100
9 5*9 5	111	—	—
10*10	100	—	—

be left alone (Figure 15 5)

Figure 15.5 *Mulch*



Some tree species have extensive root systems that probe deeply to get enough water even in low rainfall phases Young seedlings need water and nutrient regularly for first few years before their root systems develop All tree seedlings need to have abundant water to survive while their roots are growing. In mild and moderate rainfall years, artificial watering may not be required Beneficiaries in watershed areas may be required to provide water, even if it happens to be small in amount, during dry periods in the first year. The mortality of some plants in dry areas may be high This mortality may be reduced by making special arrangements to bring water from somewhere else for the first dry season Porous earthen pots may be put close to the plant and water may be filled in them regularly Porosity provides mechanism of slow release of water supply and the pots may be replenished every 48-72 hours Selection of tree species which are hardy (like *Prosopis cineraria*) and can be sown directly help in reduction of mortality.

It is also essential to ensure that unnecessary weeds do not stay in proximity of trees. Weeds compete for water and nutrient with trees So, weeding should be performed atleast twice in a year Weeds, if grow tall, may compete for light, water and air Weeding operations have bigger effects on the survival of plants as compared to watering

Tree seedlings or young trees may be destroyed by livestock, bypassers, etc Non-palatable tree species may not be eaten away by cattle If not eaten, they may be trampled by roaming cattle So, protection from grazing cattle is essential This may be possible by keeping a herder Stall feeding may also be encouraged in watershed areas Villagers may also decide to send their livestock on reserved grazing patches, thereby, keeping them out of bounds from tree planting area for several years Such social fencing requires a very high level of awareness and community mobilisation Physical barriers are expensive and require resources All types of barriers are efficient, more so if the area is not very large and is regular in shape Individual tree guards may be useful around individual trees, which are widely spaced The trenches of 1x0 5x1 2 m dimension, with excavated material piled on the inside of the trenches help in protection Seeds of thorny and hardy shrubs sown along the top of the mound improves the protection Such trench-cum-mounds are recommended where soil is clayey, silty clay or gravely. Digging of such trenches may be difficult on rocky sites In such circumstances, stones available nearby may be used to build cattle proof walls (CPW) This should be about 1 3 m high to exclude livestock The width of wall on the top and bottom depends upon the slope of the terrain and the kind of rocks available If the rocks are irregular or small, a wider wall is needed On sandy soils, trenches will collapse or fill up and stone walls may be impractical Hedge species, like Jatropa and those with thorns like Ber, Babool, Thuwar, Bombaxceiba, Agave, etc , adapted to the area may create effective biological fencing Such hedges should always be effectively placed before the trees are planted So the hedges should be sown atleast 2-3 years in advance Barbed wire fencing is a costly option hence is not recommended for watershed areas Shifting such fencing to newer blocks of saplings, as the first one grow up, may be taken up in exceptional cases A mixture or combination of vegetative hedge, CPT, CPW, barbed wire fencing may be used for protection in selected cases and situations Without permanent guards barbed wire fencing is useless

General planting principles

1 The seedlings should have long and well developed root system

2 Utmost care should be taken to avoid damage during transit.
3. Polythene containers/bags should be ripped open at the pit site, and the seedlings should be carefully lowered into the pit along with the sod of mud without disturbing or damaging roots.
4 Seedling planted in dry soils should be given more after care than in the case of wet sites.
5 The collar of the seedlings at the time of planting should be at the ground level.
6. The root system should be given its natural position and coiling should be prevented.
7 The depth of the pit should be slightly more than the seedling root.
8 Furrow/trench planting should be done in arid areas and mound/ridge planting in wet/waterlogged soils
9 Soil should be thoroughly compacted around the plant after planting, so that soil comes in close contact with the roots
10. Seedling should be partially pruned in areas with sunshine and drier climate (to reduce evapo-transpiration).
11 Mulching the soil around planted saplings with a layer of leaves, vegetation, hay, straw, etc , is helpful, as it reduces water loss through evaporation

Regeneration

It is the renewal of a forest crop by artificial or natural means When the old crop is removed or harvested, establishment of new tree crop (three-tier crop) is a pre-requisite for sustained yield Regeneration is essential for the continuity of forest. It may be said that natural regeneration should be chosen, if it can be done at a reasonable cost, with reasonable certainty and in reasonable time

Natural regeneration

Natural regeneration depends upon seed production,seed dissemination, seed germination and establishment Seed production in a natural forest depends upon the age of tree, climate, edaphic condition, crown spread, root space and other extraneous factors Best quality seeds are obtained from

— middle aged trees (neither immature nor hypermature)
— medium sized mother trees
— trees in good edaphic condition
— trees in warmer climate
— large, fully developed, light crowned trees

Though seeds may well be prematurely produced by extraneous factors like fire, injury, fungal attack, etc The seeds so produced are poor in quality Natural regeneration may be defined as renewal of a forest crop by self-sown seeds or by coppices or root suckers This may happen from seed or/and vegetative parts of trees When the forest crop is obtained from seed, it is termed as *seedling crop*, and when the crop is obtained from coppice then it is termed as *coppice crop*

(a) Natural regeneration from seeds

The regeneration is possible due to natural processes like seed production, dispersal, germination and seedling establishment The young crop is established by the natural process of colonisation and succession But it is sometimes not possible or not suitable The establishment of seedling depends upon root development, light conditions, soil conditions, crop composition, competition among tree crops, biotic factors like grazing, burning, lopping, browsing, etc., and climatic factors like rainfall, temperatures, etc So, it is necessary to manipulate the shade conditions, light conditions, mother tree distribution, slash disposal, weeding, fire control and other management practices Seeding is usually possible from the scattered trees. Such 'seed trees', besides providing the seeds, also provide protection to the site. For seeding in a specific area a certain number of seed trees are required, the number varies with species. One seed tree of *Adina cordifolia* is sufficient for one acre, 7-8 seed trees per acre are sufficient for *Pinus roxburghii* and 12-14 for *Shorea robusta* Size of canopy affects the amount of light reaching the floor, thereby influencing seedling development. Manipulation of canopy may be required periodically This facilitates entry of light, which should be based on the requirement and tolerance of young seedlings In group regeneration method, which is useful for *deodar* and oak, regeneration is tried in distributed patches and the sizes increased with establishing regeneration In shelterwood strip method, strips of convenient width are opened and the width is broadened with establishing regeneration

(b) Natural regeneration from vegetative parts/coppicing

It is asexual form of reproduction in trees taking place from certain parts of the plant bodies Such asexual methods may produce several plants from one plant. The plants which regenerate by vegetative parts grow relatively faster and vegetative reproduction may be used as a technique for genetically improving inferior trees This method ensures perpetuation of genetic characters in future progeny. There are numerous such methods by which natural regeneration is accomplished from vegetative parts

Coppicing is shaping the stumps of tree species, which have failed to produce new shoots, to make them future trees When certain trees or plants are cut from near ground level, they produce a flush of fresh shoots These are commonly called *coppice shoots*. Regeneration from such coppice is often termed as coppicing Forest species are classified as good coppicers, bad coppicers and non-coppicers based on their coppicing capabilities/power

Good coppicers include *Acacia catechu, Albizzia spp Azadirachta indica, Anogeissus spp, Butea monosperma, Eucalyptus globulus, Emblica officinalis, Salix spp, Shorea robusta, Syzygium cumini, Tectona grandis, Dalbergia sissoo, Prosopis juliflora*, etc

Bad coppicers include *Adina cordifolia, Bombax ceiba, Casuarina equisetifolia, Pterocarpus marsupium Terminalia tomentosa*, and *Quercus incana*

Non-coppicers include *Aurocaria spp, Abies spp, Cedrus spp, Picea spp*, and *Pyrus spp*

Coppicing power is the power or capacity to produce new coppice shoots It is different for different species and depends upon the age of the stump With the increase in the girth size of the tree, the coppicing power decreases

Age of the tree With older trees, the coppicing power is less

Season of coppicing The best suitable season is just before the normal shoot extension is due to begin

Height of the stump More the height of the stump, more is the coppicing occurrence.

Rotation: Short rotation coppice is best one

Silvicultural system: Clear felling results in best coppicing.

The coppices may be of two different varieties:

(i) *Seedling coppice*: Established seedlings sometimes may not attain good growth in height and diameter In such cases, they are cut back near to the ground and overhead shade is cleared The new shoots appear at and below the cut surface Only a leading shoot, nearer to the ground level, is retained. This retained shoot grows vigorously and is comparable to the normal growing seedlings in a few years

(ii) *Stool coppice*: After felling the trees, stools are trimmed or shaped giving it a slight gradient. The shoots nearer to the ground are retained

Pollarding: In this method, stem is cut off, usually above the height to which browsing animals can reach, a new flush of shoots begin This creates copious biomass in the existing vegetation Strong shoots, so produced, may be used for variety of seasons. This method is utilised for *Grewia oppositifolia, Hardwickia binnata, Morus alba,* and *Salix spp*

Artificial regeneration

Numerous factors determine the choice of artificial/natural regeneration As a rule, artificial regeneration is used as a supplement

- to support scanty natural regeneration,
- to introduce fast growing and more productive new species,
- to cover up, degraded denuded areas especially, in susceptible places like eroded lands, gullies, ravines, shifting sand dunes etc.,
- to convert the composition of the trees in the area, so that the vegetation fulfils all the demands of the community, and
- to restock the degraded forests

This method is the renewal of a forest crop by sowing, planting or other artificial methods.

16

Grassland Management

One of the most important components in rainfed agriculture is livestock Out of the 304 21 million hectares (m ha) of reported area, the available land resources for grazing are as under.

Land resource	*Percent*
Forest cover	22 13
Permanent pasture	3 94
Miscellaneous tree crops and grooves	1 14
Cultivable wasteland	5 08
Fallow lands	7 52
Total	39 81

All these resources are able to meet the fodder requirement of the grazing animals only during the monsoons For the remaining periods of the year, there has always been a shortage of fodder and grasses Most of the villagers in India are forced to feed their cattle with crop residues from wheat, paddy, *bajra, jowar, ragi,* sugarcane, barley, etc

More than 12 million hectares have been reported as permanent pasture and other grazing lands Most of such land is cultivable, but it is commonly being used as permanent pasture and meadows in hill slopes and village common lands in the plains Most of these lands have been encroached for agriculture/cultivation or for residential purpose.

From 1951 to 1971, human population in India increased by 52% from 361 to 541 million It is expected to touch 931 million mark by the turn of the next century The per capita availability of land for production of food, fibre etc, shrunk from 0 33 ha to 0 292 ha, and this will be further decreased to only 0 175 ha by 2000 AD This has caused great biotic pressure on grasslands, resulting in overgrazing which invariably leads to massive soil erosion The analysis of the availability of fodder along with the livestock population demand in India suggests that there is a huge gap between demand and supply of all kinds of feed and fodder (Table 16 1). This deficit is likely to increase, because the animal population

Table 16.1 *Grazing pressure and existing carrying capacity*

State	*Grazing pressure (ACU/ha)*	*Existing carrying (ACU/ha)*
Andhra Pradesh	2 17	1 17
Karnataka	1 04	1 09
Maharashtra	2 24	0 97
Madhya Pradesh	1 62	0 84
Gujarat	6 03	0 76
Rajasthan	7 68	0 68

is increasing annually by 2% For estimation of stocking rates, the livestock population is represented in a uniform unit of Livestock Standard Unit (LSU) or Animal Cattle Unit (ACU) which is taken as an equivalent to 250 kg live body weight The conventional equivalents are as follows

1 one head of cattle (>3 years age) = 1 0 ACU
2 one head of cattle (<3 years age) = 0 5 ACU
3 one adult buffalo = 1 25 ACU
4 one buffalo (<3 years age) = 0 6 ACU
5 one sheep/goat = 0 17 ACU
6 one horse/ass = 1 2 ACU
7 one camel = 1 5 ACU

The grazing pressure is more in semi-arid and arid areas Hence, there is a need for augmenting the fodder availability. The National Commission on Agriculture (NCA) has provided the average rates of feeding the livestock, which may be used to calculate fodder and concentrate requirements in any watershed area (Table 16 2)

Table 16.2 *Average rates of feeding the livestock (rates of feeding per day)*

Category of livestock	*Concentrates (kg)*	*Green fodder (kg)*	*Dry fodder (kg)*
(a) Cattle			
(i) Crossbred(milch)	2 75	20 00	6 00
(ii) Females 3 years age			
(a) Improved cows(milch)	1 20	10 00	6 00
(b) Other milch cows and those not calved even once	0 125	3 50	3 16
(iii) Males 3 years age	0 17	4 96	5 65
(a) Crossbred (young stock)	1 50	10 00	2 00
(b) Other young stock	0 016	1 58	1 47
(b) Buffaloes			
(i) Female 3 years age			
(a) Improved buffaloes	1 50	10 00	6 00
(b) Other milch buffaloes and those not calved even once	0 41	5 72	5 08
(ii) Males 3 years age	0 11	6 57	5 43
(iii) Males/females 3 years age	0 01	1 59	1 64
(c) Other livestock			
(i) Improved sheep	0 28	—	0 40
(ii) Horse and ponies	0 50	—	—

Subsequently, total fodder requirement and potential in the watershed can be calculated. There will be a deficiency of green fodder or dry fodder or both, which then can be emphasised in the fodder/pasture development strategy of the watershed

Role of grasses in soil and water conservation

Grasses or grass plants, have a capacity to prolong the hydrologic cycle, from its inception as falling precipitation to its final disposal as runoff in streams The grasses control water erosion by three-tier action·

(a) *The first tier*: The protection is offered above the ground through the dense thatched roof action of the leaves and stems of grasses. This exposes innumerable little surfaces, whose aggregating area is several times greater than that of the ground beneath This helps in dispersion, interception, energy dissipation and evaporation of the falling raindrops.

(b) *The second tier*: This is offered by the grass bushes at the ground floor Resistance against erosion and runoff is offered through mechanical resistance by plant clumps, or runners and by the protective blanket of litter mass of leaves and fragments of stems in various stages of disintegration This also performs double function of increased surface friction which helps in reduction of volume and velocity of runoff and in absorbing a major part of water for deeper percolation.

(c) *The third tier* This is offered directly in the soil mass. The knitting and binding effect of grass root and rhizome system protect the soil from detachment, disintegration and washing. The ramifying, close and elaborate network in all directions of grassroots holds the soil particles together and provide a mesh of compactness and reinforcement that anchors the erosive action of water flowing over it

The grasses offer a lot to choose from, for protection or production or for both. Grasses provide a rich variety of characteristics like ease in establishment, perennial nature, bunch, mat, sod, sword and turf formation, adaptability to a variety of edaphic and climatic conditions, amenability to various management practices and systems like sowing, cutting, etc For protection, stabilisation and consolidation of the soil on earthen conservation structures like contour terraces, contour trenches, checkdams, field bunds, diversion channels, waterways, waste weirs and spillways etc , grasses are a formidable and effective method (see Plates 43, 44, 45 a,b).

Management of grasslands

Stability of grassland vegetation, in particular and soil, in general, is affected by grazing The management of grassland depends upon its type/variety That is, grassland in the humid, the dry, the temperate and the tropical are to be evaluated and managed differently In their natural condition, grasslands are generally made up of numerous species of grasses, herbs and shrubs There is a logical relationship among all such species and between these species, climate and soil The inter-relationship between grasses and soil or vegetation could easily be observed in watershed areas The better the soil and the climate, the more luxuriant and productive will be the grasses Good grass cover provides a protective barrier for the soil The management of the grasslands, especially in upper reaches of watershed, is important as constant and enriching biomass would help conserving soil and moisture and

Plate 43 *Vast unutilised and unprotected areas could be developed into grasslands by promoting local available grass variety and necessary protection*

Plate 44 *Alongwith natural (indigenous) grasses, soil enriching perennial legumes like Stylosynthes hamata should be promoted on grass beds in arid and semi-arid areas*

Plate 45 (a, b) *Availability of fodder in lean season create opportunities for other income-generating activities Fodder storage and processing (silo or hay making) becomes a necessary step*

would create environs for other advanced tree species to regenerate and/or planted The management of grassland is simply the regulation of the use of the vegetation/biomass, so as it is preserved in its highest state of protection and production

If the vegetation cover is lost, the soil is lost and with the loss of soil, the resource vanishes If the soil is partly lost, and then stabilised with pasture or grassland development on deteriorated and eroded wasteland, the resource is partly restored. Full restoration of the soil is a very long term process. So, a practical option is to develop and maintain a cover adequate for soil stability at the earliest If the edaphic system is stable, then maintenance of that stability and improvement of soil and vegetation may often be achieved by manipulating the grazing Even with the soil erosion prevailing in a watershed, simple grassland management practices and techniques may increase the amount of vegetation, topsoil remains intact and there is a sufficient stand of erosion-preventing perennials to provide seed source, then stabilisation of wastelands by grasses could be easily managed When this requirement cannot be met, then other measures like artificial mulching, artificial planting by seed disposal or sapling or even construction of soil and water conservation structures like contour trenches etc may have to be considered

The management of grassland serves the secondary, though an equally important, function of harvesting the products of the land For the watershed management,these products are continuing supply of fodder and forage For the purpose of water yield, grasses which use least water in transpiration are the most desirable Though, a certain minimum cover has to be maintained to protect soil and moisture optimally Generally, shallow-rooted species consume less soil water than deep-rooted species Not much is known about water consumption requirement and soil protection potentials of different species A specific recommendation, hence, is not possible and desirable in preferring one type over another. The situation is different with forage Various types and sub-types of forages are known to be more desirable than others. The objective in grassland management should therefore be to develop a combination of fodder and forage species, within the productive potential of the site, considering edaphic and climatic conditions

Cutting and stallfeeding of grasses is considered best, though most villagers or beneficiaries in the watershed area may not adopt stallfeeding Numerous methods of regulating grazing are prevalent

(i) *Controlled grazing*: It means regulation of grazing on the basis of carrying capacity for year-long grazing or seasonal grazing or deferred grazing or rotational grazing The livestock are not allowed to roam in the fields unattended and few places/pasture lands are opened for grazing and others are closed for grazing

(ii) *Early versus deferred grazing* Deferred grazing is basically postponing or delaying grazing, either completely for the entire growing season (complete deferment) or for the beginning of the growing season (early deferment) or for the late part of the growing season (late deferment) to enable the vegetation to grow well. Grazing is allowed only after seeding (usually from mid-October), but may have to be withdrawn after a few years

(iii) *Rotational grazing* This is year-long grazing in blocks or compartments in rotation. The goal is to give rest to the land, thereby creating opportunity for vegetation to grow and develop well It is advisable to divide the entire grazing land into three blocks

Rest for two years in each block should be ascertained.

(iv) *Deferred-rotational grazing*: Here, all the three blocks are used each year changing the sequence of grazing in a way that each block is grazed for one-third year and protected for two-third year. It is better to have this system of grazing on the basis of the development of the range vegetation rather than a fixed period of time

Grazing livestock influence the grasslands in three ways

(a) *Removal of herbage*: Injury done to grasses by heavy grazing reduces the photosynthetic area and drains its food reserves. Under certain conditions, grazing may have a stimulating effect on growth. If the grazed grasses are given sufficient opportunity to make substantial re-growth, foliage removal may not be injurious Heavy grazing affects the vegetation as a whole, by handicapping preferred species and favouring less palatable species. It also reduces the amount of foliage cover and litter, creating a drier micro-environment at the ground surface, which may result into heavy soil erosion. Certain species are more adapted than others, in any given situation through growth form, rapidity of development or otherwise to grazing. Some other species, escape grazing at a time infavourable to them, because they are palatable only late in the season after their growth cycle is complete. Others have a protective cover of thorns which prevent them from being grazed Thus, more palatable grasses decrease, while adapted species tend to flourish The obvious aim of grassland management will be to reduce these undesirable species and to promote preferable and palatable varieties

(b) *Dissemination of seeds* This influence is universal in nature, but it is more dramatically evident where a grassland has been heavily grazed and trampled Annual plants and others, having low quality for forage and which are of little value for giving protection to the soil, become established along trails and on rest grounds where the better plants have been destroyed Grazing animals have been a constructive factor in the invasion and spread of some perennial herbs and grasses, which to a certain extent check erosion In normal circumstances, bare spaces between the clumps of vegetation are either covered with litter or are underlain with roots from healthy plants

(c) *Trampling of soil* It not only damages plants but it may damage the soil as well The effects are more marked in the compaction of fine-textured soils when wet Rainwater is then likely to flow off the surface, carrying along with it topsoil, instead of soaking into the ground and replenishing the soil moisture supply Soil displacement by trampling may also directly cause soil erosion Infiltration capacity is directly proportional to the amount of herbaceous material left Therefore, it is possible that where soils are heavily grazed their already low storage capacity may be only partly utilised because water cannot enter the soil rapidly.

The diversity of forage plants is of special significance and importance in grazing management This ensures species with different degrees of palatability, different patterns of seasonal development and growth forms For good management of grassland, the habits of growth, flowering and reproduction, palatability and the time and intensity of utilisation of the different species should be understood A vegetative biomass, thus created, will contain a predominance of preferred grass and plant species of perennial life form

The biggest and most serious problem in grassland management is to balance the number of animals with the grazing capacity. This lack of balance is further increased by scanty forage production, poor development and low production in lean seasons and serious soil erosion. Grazing capacity is defined as the ability of a grassland unit to give adequate support to a constant number of livestock for a stated period each year without deteriorating proper land use. The amount of forage a plant can furnish depends upon the preference of animal for it, its edibility or palatability, the amount of herbage which must remain on the plant to produce efficient plant food and its ability to withstand grazing A desirable forage plant must be able to compete grazing with other forms and species of vegetation, to provide a protective cover of biomass to guard against soil erosion and to rebuild sites that have deteriorated. They should possess strong seeding habits, ability to spread vegetatively and a large root system which can withstand wide variations in soil-moisture and temperature conditions and trampling by livestock

The effect of grazing will depend largely on the degree to which the forage is utilised. The quantity of herbage left after grazing will govern the growth and development of forage plant roots. The rate of root development depends on the availability of carbohydrates. Heavy grazing reduces surplus carbohydrate production which are needed primarily to replace the parts that have been cropped. Root growth and retention storage availability are reduced accordingly. The management of a grassland by balancing the number of livestock with grazing capacity cannot be ascertained on the basis of individual plants but rather on the aggregate of all the forage producing vegetation Particular attention should be paid to certain key species which furnish a large part of the forage and which must be maintained in high vigour. Such plants should not be grazed beyond their safe limit, even though there appears to be considerable ungrazed herbage remaining. Grazing capacity should not include heavy utilisation of the less desirable plants because under such a practice, the more desirable and palatable plants will be overgrazed Considerable herbage from ungrazed or partially grazed plants left on the ground is important in maintaining or rebuilding good edaphic situations Physical and biological deterioration of soil, brought about by a lack of balance between number of animals and the forage supply, reduces the production of both forage and animal products

With the introduction of grazing in otherwise protected grassland, the most palatable and most desirable types of plants are overgrazed, their growth becomes stunted, the root reserves are depleted and exhausted and the shoots become shorter and smaller With continued overgrazing these desirable plants die, leaving some part of the ground surface unoccupied momentarily, which may soon be invaded by seedlings of less desirable types of plants With the continued exploitation and destruction by grazing , the next most desirable plants begin to be overgrazed and trampled and they too give up their places At this juncture, and particularly in areas where the animals tend to concentrate, the cover may become insufficient to hold the soil and the erosion begins. The deterioration process becomes more rapid and more difficult to stop and soon the grassland is destroyed and degraded

Tables 16 3, 16 4, and 16 5 present lists of grasses, shrubs and trees for forage in arid and semi-arid areas An illustrative list of grasses and legumes according to soil type and rainfall is given in Table 16 6

Table 16.3 *Grasses for forage in arid and semi-arid conditions*

	Botanical name	*Naturally preferred Terrain*	*Other uses*	*Flowering period*
1	*Aristida adscensionis*	Sandy, rocky	Brooms	October-December
2	Visarpi ghas(*Brachiana reptans*)	Marshy	Food	October
3	Anjan(*Cenchrus biflorus*)	Sandy	Food, soil conservation	—
4	Safed Dhaman(*Cenchrus cilvaris*)	Sandy	Soil conservation	Perennial
5	Kala Dhaman(*Cenchrus setigerus*)	Marshy	—	—
6	Duub(*Cynadon dactylon*)	Marshy	—	—
7	Motha(*Cyperus rotundus*)	Wasteland, marshy	*Agarbatti* manufacturing	April-October
8	*Dactyloctenium sindicum*	Sandy	—	April-September
9	Daab(*Desmostachya bipinnata*)	Sandy	Medicinal, soil conservation	July-September
10	*Dicanthium annulatum*	Marshy	Medicinal, soil conservation	September-February
11	Homa(*Echinochloa colonum*)	Sandy, marshy	Food, religious ceremonies	April-October
12	*Echinochloa crusgalli*	Marshy	Soil conservation	April-October
13	Underpuncha hotti (*Eragrostis ciliaris*)	Sandy, marshy	—	April-October
14	*Eragrostis diarrhena*	Sandy, marshy	—	July-September
15	Phoolan ghass(*Eragrostis tremula*)	Sandy, rocky	Soil conservation	April-October
16	Laab (*Heteropogon contortus*)	Sandy	Food, medicinal, soil conservation	October-November
17	Sewan(*Lasiurus sindicus*)	Sandy	Food, soil conservation	October-November
18	Murratghaas(*Panicum antidotale*)	Sandy	Food, soil conservation	September-November
19	Murtghas(*Panicum turgidum*)	Sandy, marshy	Food, soil conservation	—
20	*Phalaris minor*	Sandy	—	—
21	Baaru(*Sorghum halapense*)	Marshy	—	—
22	Sitaghas(*Tragus biflorus*)	Sandy	—	July-September
23	*Tragus roxburghii*	Rocky	—	October-November
24	*Brachiara ramosa*	Sandy	—	April-October
25	Moth (*Cyperus elusinoides*)	Marshy	Medicinal	Perennial
26	*Echinochoa crusgalli*	Marshy	Soil conservation	April-October
27	*Eragrostic tenella*	Sandy rocky	—	August-October
28	Karaar(*Lseilema prostratum*)	Sandy, rocky	Soil conservation	October
29	*Sporobolus tremolus*	Sandy	Soil conservation	—
30	*Tetrapogon tenellus*	Sandy	—	—
31	Gharaniaghass (*chloris virgata*)	-	—	July-September
32	(Dinanath)*Paspalidium flavidium*	Marshy	Food	July-October
33	*Pennisetum pedicellatum*	Wasteland	Soil conservation	—
34	Kaans (*Saccharum spontaneum*)	-	Fibre medicinal	September-October

Table 16.4 *Shrubs for forage in arid and semiarid condition*

1	Dabi/Dabia(*Abutilon indicum*)	Mashy	Fibre, medicinal	October
2	Baonali(*Acacia jacquemonli*)	-	Fibre, soil conservation	Jan -April
3	Jungli cholai(*Amaranthus viridis*)	Sandy	Food	April-Feb
4	Bhangri(*Blephasis linaraefolia*)	Sandy	-	Sep -October
5	*Borreria articularis*	Sandy	Medicinal	July-September
6	Phog(*Calligonum polygonoides*)	Sandy	Timber, fuelwood, food, medicinal	April-May
7	Sannia(*Crofolaria burhia*)	Sandy	Fibre, medicinal, soil conservation, rope making	Sep -December
8	Gulali(*Crotolaria medicagenia*)	Marshy	-	April-October
9	*Digera muricala*	Marshy	-	April-September
10	Laana(*Haloxylon salicornicum*)	-	Fuelwood, food, colour	-
11	Karma/kalmi(*Ipomea aqualica*)	Marshy	Fuelwood, food	July-April
12	*Ipomea pestigridis*	Marshy	-	Sep -October
13	*Polygonum barbatum*	Marshy	Medicinal	October
14	Jungli kulfa(*Portulataca oleracea*)	Sandy	Food	March-April
15	*Rhynchosia minima*	Sandy	-	-
16	Sajji(*Salsola griffithi*)	-	Dying clothes, decrease salinity	April-Sep
17	Dadon(*Sesbania bispinosa*)	Marshy	Fuelwood, organic fertiliser	April-November
18	Bhidnali/miunil(*Sida cordata*)	Sandy	-	Perennial
19	Safed satta (*Trianthema portulacastrum)*	Sandy	-	July-Nov
20	Jawasa(*Alhagi pseudalhagi*)	-	Medicinal, manufacturing *chatai*	May-June
21	*Alternathera sessilis*	-	Good for milch cattles	Perinnial
22	*Desmodium triflorum*	-	-	October
23	*Digera muricata*	Sandy	-	April-Sep
24	Dasni/dasri(*Rhus mysyrensis*)	Slopy wasteland	Fuelwood, food, fibre, medicinal	July-August
25	Lagera(*Sericostoma pauciflorum*)	Slopy wasteland	Fibre, medicinal	March-April
26	Dhamasia(*Tephrosia purpurea*)	Sandy, slopy wasteland	Medicinal	April-October
27	Chota-Ghokru(*Tribulus terristris*)	Sandy	Medicinal	May-April
28	*Zornia gibbosa*	-	-	Sep -Nov
29	Karonda*(Carissa congesta*)	-	Food	Jan -April
30	Jungli gobi(*Launaea procumbens*)	Wasteland	Food	Feb -April
31	Sandri(*Veroniva cinerea*)	Slopy wasteland	Medicinal	-
32	Kaanti(*Acanthospermum hispidum)*	-	Food, medicinal	Sep -Nov
33	Chui-mui(*Aeschynomene indica*)	-	Fuelwood	Aug -January
34	Bachuti(*Amplocissus latifolia*)	-	Medicinal	May-June
35	Rizva alfalfa(*Medicago sativa*)	-	Food, scents, soil conservation	Feb -April
36	Khandai/Klovare(*Melilotus alba*)	-	Soil conservation	-
37	Jungli Paalak(*Rumex dentatus)*	-	-	Sep -Oct
38	Gubba(*Laucus urticifolia*)	-	-	Sep -Oct
39	Ninhad(*Vitex negundu*)	-	Insect repellant	April-September

Table 16.5 *Trees for forage in arid and semi-arid conditions*

	Botanical name	*Naturally preferred terrain*	*Other uses*	*Flowering period*
1	Babool*(Acacia nilotica)*	Sandy, rocky, marshy	Small timber, fuelwood, fiber, medicinal, scents, soil conservation	Sep -March
2	Siris*(Albizia lebbek)*	Wasteland, marshy	Small timber, fuelwood, medicinal, scents	April-Sep
3	Dhao*(Anogeissus pendula)*	Rocky	Small timber, fuelwood, fiber	April-Sep
4	Neem*(Azadirachta indica)*	Sandy	Small timber, fiber, medicinal, scents, soil conservation	April-May
5	Kail*(Capparis decidua)*	All terrains	Small timber, fuelwood, medicinal	Perennial
6	*Cassia siamea*	Sandy	Small timber, fuelwood, soil conservation	Oct -Feb
7	Aruni*(Clerodendrum phlomidis)*	-	-	Perennial
8	Shisham*(Dalbergia sissoo)*	-	Small timber, fuelwood, toys	March-April
9	Kekar*(Parkinsonia aculeata)*	-	Fuelwood	Perennial
10	Khejari*(Prosopis cineraria)*	All terrains	Small timber, fuelwood, religious, medicinal, soil conservation, scent, fibres	March-April
11	Vilayati Babool *(Prosopis juliflora)*	Sandy, rocky	Fuelwood, soil conservation	Jan -March
12	Ber*(Zizyphus mauritiana)*	Sandy, rocky	Food, medicinal	Apr -Oct
13	Jhud-Ber*(Ziziphus nummularia)*	Sandy, rocky	Food, medicinal	Feb -June
14	Bel*(Aegel marmelos)*	-	Food, medicinal, religious	Apr -June
15	Maharuk*(Ailanthus excelsia)*	Slopy wasteland	Small timber, fuelwood, medicinal, soil conservation	Feb -March
16	Kala siris*(Albizzia odoratissima)*	-	Small timber, fuelwood	Apr -June
17	Kaladhaon/Dhawra*(Anogeissus latifolia)*	-	Small timber, fuelwood, medicinal, edible gum, scents	Oct -June
18	Semla/Koiral*(Bauhinia retusa)*	-	Small timber, fuelwood, fibre, gum, medicinal	Sep -Nov
19	Kachnar*(Bauhinia variegata)*	-	Small timber, fuelwood, fiber, medicinal	Feb -Apr
20	Salaar*(Boswellia serrata)*	Slopy wasteland	Small timber, fuelwood, medicinal, scents, gums	Jan -Feb
21	Dhak/Flame of the forests *(Butea monosperma)*	Slopy wasteland, rocky	Small timber, fuelwood, fiber, medicinal, scents, colours	Jan -Apr
22	Uari*(Saccopetalum tomentosum)*	Slopy wasteland	Small timber, fuelwood	Apr -June
23	Rohira*(Tecomella undulata)*	Slopy wasteland	Small timber, fuelwood, medicinal, soil conservation	Feb -Apr
24	Samul*(Bombex ceiba)*	Slopy wasteland	Small timber, fuelwood, fibre, cotton	Feb -March
25	Kanchanb*(Bouhinia racemosa)*	Slopy wasteland	Small timber, fuelwood, fibre, bidi, medicinal	Mar -June
26	Sahoal*(Bouhinia malabanica)*	-	Small timber, fuelwood	Apr -Oct
27	Koylera*(Bauhinia pupurea)*	-	Small timber, fuelwood	Sep -Nov
28	Tun*(Sedrella tuna)*	Slopy wasteland	Small timber, fuelwood	Feb -March
29	Dhobian*(Dalbergia paniculata)*	-	Small timber, fuelwood	June
30	Sanjena/Drumstick*(Moringa oleifera)*	Slopy wasteland	Fuelwood food medicinal	Jan -Apr
31	Kadam*(Mitragyna parifiora)*	-	Small timber, fuelwood, food	July-Sep
32	Jungle jalebi *(Pithecellobium dulce)*	-	Fuelwood, food	Mar -Apr
33	Mokha*(Schrebera swietenoides)*	-	Small timber fuelwood, food, medicinal	May-June
34	Rohan*(Soymada befifugal)*	-	Small timber, fuelwood, food, medicinal	Apr -May

Table 16.6 *Selection of grasses and legumes according to soil type and rainfall*

Rainfall zone(mm/yr)		Major soil type	Suitable grasses	Suitable legumes
1	<200	Sandy soil	*Panicum antidotale* *Lasiurus sindicus* *Cymbopogon sp*	—
2	200-400	Alluvial soil	*Cenchrus ciliaris* *Cenchrus setigenus*	*Clitoria ternata*
3	400-600	Red sandy loam	*Cenchrus ciliaris* *Chrysopogon fulvus* *Heteropogon*	*Stylosanthus* *hamata* *Botheriochloa* *pertusa*
		Black clay loams	*contortus* *Dichanthium* *annulatum*	
4	>600	Loam to clay loam soil	*Pasicum maximum* *Napier hybrid,* *Setaria sphacelata*	*Stylosanthus* *hamata,* *Sirataro*
		Rocky degraded	*Sehima nervosum*	—

Grasslands in India

According to the land utilisation statistics, the area under permanent pastures and grassland is 13 m ha In addition, there are another 15 m ha classified as cultivable wasteland and still another 7 m ha under the saline and alkaline soils The grasslands on the contrary are essentially the monsoon grasslands and grasses in them show their best biological potential for a period of about four months, after which they go into dormancy phase

The grassland survey carried out by the Indian Council of Agricultural Research (ICAR) has led to the recognition of four distinct grass covers in the plains and the lower hills and one at high altitudes.

Tropical and sub-tropical grasslands

Four main grass covers have been recognised in the tropical and sub-tropical parts of the country as described below

(i) *Dichanthium-cenchrus-lasiurus cover* is distributed in northern Gujarat, Rajasthan, western Uttar Pradesh, Haryana, Punjab and Jammu & Kashmir The chief forage species are *Dichanthium annulatum, Cenchrus ciliaris, C setigerus, Lasiurus sindicus and Sporobolus marginatus*

(ii) *Sehima-dichanthium* is the largest grassland cover and is distributed in the Central Plateau, Chhota Nagpur, the Aravalli ranges. Andhra Pradesh, Gujarat, Kerala, Madhya Pradesh. Maharashtra, Orissa, Tamil Nadu, south-west Bengal, southern Bihar, the eastern hilly portion of Uttar Pradesh and Rajasthan The dominant forage species are *Sehima nervosum, Dichanthium annulatum, Iseilema laxum, Ischaemum indicum, Themeda triandra, Chrysopogon fulvus* and *Heterpogon contortus*

(iii) *Phragmites-saccharum-imperata cover* mainly consists of tall coarse species exclusively utilised for thatching huts and in rope-making It is found in the humid and sub-humid regions of the Gangetic plains and in the Brahmaputra Valley The chief species are *Phragmites karka, Saccharum spontaneum, Erianthus munja,* and *Imperata cyclindrica*

(iv) *Themeda-arundinella* is distributed in Manipur, Assam, West Bengal, Uttar Pradesh, Punjab, Himachal Pradesh, Jammu & Kashmir upto to an altitude of 2100 m Important economic grass species of this cover are *Themeda anathera, Arundinella nepalensis, Chrysopogon fulvus, Heteropogon controtus*, etc

Alpine, sub-alpine and temperate regions

The temperate alpine cover is found in the high hills of the northern montane belt comprising Jammu & Kashmir, Himachal Pradesh, Punjab, Uttar Pradesh, West Bengal and Assam. The chief forage species are *Agropyron spp , Agrostis spp , Dactylis glomerata, Phleum alpinum, Poa pratensis, Festuca ovina, Festuca rubra and Bromus ramosus.*

Due to continuous exploitation and misuse of grasslands, for centuries in the past, the proportion of perennial species has considerably dwindled, resulting in the preponderance of annual, inferior and less palatable grasses, coupled with a high density of undesirable bushes and shrubs.

Important fodder plant species suitable for different agro-climatic regions of India are given in Table 16 7

Protection of grasslands

Survey and protection

The condition survey of the grassland should be conducted to assess the botanical composition and the overall percentage of grasses present in them. Depending upon the physical statistics, decisions regarding the protection against uncontrolled grazing or complete renovation through reseeding can be taken if it is felt that the desired grasses are not present in good proportion Then, offering protection to such areas would result in abundance of growth and coverage of the area within 2-3 years. For giving protection, fencing the area is a pre-requisite. Though angle-iron poles with barbed wire or woven-wire fencing is costly to begin with, yet it may prove to be economical in the long run In addition, other types of fencing material, such as cement or stone posts with wire fencing or the live hedge or thorny fencing, can be used successfully. The best live-hedge materials are Mehndi (*Lawsonia alba*), Jungle jalebi (*Inga dulcis*), *Zizyphus nummularia, Parkinsonia*, etc In the rocky terrain stones may be stacked to an optimal height to serve as stone-wall fencing The protected grasslands yield rich dividends in terms of animal gains

A new concept of social fencing has been coined under Joint Forestry Management (JFM) Essentially, it means protection by the community without any physical boundaries/protection of the area This can be tried in watershed areas with good community mobilisation Social fencing should always be the ultimate aim for protection of grasslands Through community mobilisation, JFM, and controlled grazing, some micro-watersheds in Jhabua district have effectively adopted social fencing for protection of grasslands and degraded forests.

Bush clearance

Undesired bushes and shrubs compete with grasses for space, light, nutrients, besides being

Table 16 7 *Important fodder plant species suitable for different agro-climatic regions of India*

	Name of tracts	Grasses	Legumes	Trees
1	Western Rajasthan south-east Punjab western Gujarat including Kutch and western Saurashtra	*Cenchrus ciliaris C setigerus Dichanthium annulatum Panicum antidotale Lasiurus sindicus,* etc	Atylosia scarabaeoides, Macroptilium atropurpureum, Rhynchosia minima, Dolichos lablab, etc	*Acacia tortilis, Albizia amara Azadirachta indica, Dichrostachys cinerea, Hardwickis binata, Prosopis cinerea, P juliflora Leucaena leucocephala*, etc
2	Central Punjab eastern Rajasthan western Uttar Pradesh northern Gujarat Maharashtra western Madhya Pradesh Andhra Pradesh Tamil Nadu and Karnataka	*Cenchrus ciliaris, C setigerus, Dic-hanthium annulatum Heteropogon contortus Pancium antidotale, Pennisetum pedicellatum Sehima nervosum, Cynodon plectostachvus* etc	Atylosia scarabaeoides, Clitoria ternatea, Lablab purpureus, Macroptilium atropurpureum, Mucuna deeringiana Stylosanthes hamata, S scabra, S viscosa, Dolichos lablab, Stylosanthes humilis, etc	*Acacia tortilis, Albizia amara, A lebbe A procera, Azadirachta indica, Dalbergia sissoo, Hardwickia binata, Leucaena leucocephala*, etc
3	Central and eastern Uttar Pradesh southern Bihar southern Gujarat, coastal Andhra Pradesh and coastal Tamilnadu	*Brachiaria mutica Cenchrus ciliaries Cynodon dactylon Dichanthium annulatum Panicum antidotale P maximum Paspalum notatum, Pennisetum pedicellatum, P polystachyon, Setaria sphacelata, Brachiaria mutica, B brizantha, Chloris gayana* etc	Macroptilium atropurpu-reum, Centrosema pubescens Glycine javanica, Glycine wightii, Mucuna deeringiana, Pueraria phaseoloides, Stylosanthes quianensis, Stylosanthes gracilis, Dolichos lablab, Stizolobium deeringianum, etc	*Albizialebbeck, Anogeiss-us latifolia Azadirachta indica, Erythrina variegata, Gliricida sepium Ficus Sp, Leucaena leucocephala, Morus alba, Moringa oliefera, Tamarix aphylla*, etc
4	West Bengal Assam, Orissa eastern Madhya Pradesh	*Brachiaria mutica, Cynodon dactylon, Dichanthium annulatum Panicum maximum Pennisetum clandastium P pedicellatum, Setaria sphacelata, Urochloa mosambicensis Panicum repens*, etc	Calopogonium mucoroides, Centrosema pubescens, Desmodium spp Stylosanthes quianensis, Vigna umbellata, Stylosanthes gracilis. Phaseolus calcaratus, etc	*Albizia lebbeck, Bauhinia purpurea Gliricidia sepium, Moringa oleifera, Morus alba*, etc
5	Lower hills of Punjab Himachal Pradesh Uttar Pradesh and West Bengal	*Chrysopogon fulvus Dichanthium annulatum, Pennisetum pedicellatum, Iseilema laxum Thameda anathera Arundinella spp* etc	Atylosia scarabaeoides, Dolichos lablab, Macroptilium atropurpureum, Stylosanthes hamata, S humilis, S scabra, Sirato, S gralicilis, etc	*Albizia amara, A lebbeck Azadirachta indica, Ficus sp* etc
6	High hills of Uttar Pradesh Himachal Pradesh Punjab and Jammu & Kashmir	*Dactylis glomerata Lolium perenne, L multiflorum, Festuca anundinacea Poa sp, Bromus spp*, etc	Lespedeza cuneata, Medicago sativa, Trifolium pratense T repens M falcata, T subterraneum etc	*Grewia optiva, Quercus incana, Robinia pseudoacacia, Salix*, etc
7	Valleys of Uttar Pradesh, Madhya Pradesh, Gujarat and Bihar	*Chrysopogon fulvus, Cenchrus ciliaris Dichanthium annulatum Pennisetum pedicellatum, Cenchrus setigerus Heteropogon contortus*, etc	Macroptilium atropurpureum, Mucuna deeringiana, Puesaria phaseoloides Dolichos lablab, Stizolobium niveum, S deeringianum, etc	*Acacia tortilis Dichrostachys cinerea, Prosopis juliflora*, etc
8	Usar(saline and alkaline)areas of Punjab, Haryana Uttar Pradesh Rajasthan and Gujarat	*Brachiaria mutica Bothriochloa pertusa, Chloris gyana Cynodon dactylon, Dichanthium annulatum, Iseilema laxum Panicum maximum, Setaria sphacelata Sporobolus marginatus*, etc	Alysicarpus rugosus, Desmenthus virgatus, Rhynchosia minima, Sesbania aegyptiaca, S acculeata Atriplex sp Acacia arabica Prosopis cineraria, etc	*Acacia tortilis, Dichrostachys cinerea, Leucaena leucocephala, Prosopis juliflora, Sesbania grandiflora*
9	In swampy areas	*Brachiaria mutica, Iseilema laxum* etc	Lotononis bainisii, Sesbania bisinosa, etc	*Salix sp*

poisonous to the grazing animals Common bushes, namely, Jharberi *(Zizyphus nummularia)*, Dhak *(Butea monosperma)*, *Carissa spp*, *Lantana spp* and *Mimosa* should be cut manually at ground level

In inaccessible areas or on steep slopes where the complete bush clearance would lead to serious soil erosion and it would be difficult to establish the grass-legume components, very little soil-working is necessary. Even the protection of grasslands without bush clearance increases the dry grass yield to 5 5 q/ha, as compared to 0 8 q/ha from the unprotected area The yield of dry grass can be increased to 40-42 q/ha with complete protection and bush clearance.

Adoption of soil and water conservation measures

In undulating topography adequate soil and water conservation measures, viz., pitting, contour-bunding and contour-furrowing should be adopted The harvesting of rainwater by plugging gullies, streams or *nallas*, especially in the areas with undulating topography or to put the check bunds at several points on a stream is done so as to harness water for utilisation during the periods of moisture stress (November onwards) for rejuvenating the grasses Similarly, the low lying areas vulnerable to frequent floods are drained of excess water, which is utilised during the period of moisture stress for increasing fodder yields

Reseeding with better species

Under the completely denuded and worst condition of the grassland, reseeding with better-yielding, adaptable, persistent and aggressive species becomes essential The technique of reseeding is quite simple and can be followed successfully It involves the following steps

(a) The land is cleared of undesirable bushes At the time of the final land preparation, 25-30 cartloads of farmyard manure (FYM) per ha should be thoroughly mixed with the soil

(b) Grass seeds, being very small, light and with appendages are very likely to be washed or blown away by the currents of water or wind Thus, for efficient and easy re-seeding, the seed is processed into small pellets which are easy to handle and are less vulnerable to water and wind currents The seed is worked into a homogeneous thick paste, made by mixing three parts of sand, one part of clay, cowdung and fertiliser By above process pellets of convenient size are prepared in such a way that each pellet contains two or three seeds

(c) Enhancing herbage quality through legumes The nutritive value and palatability of these grasses can be increased at least two-fold by overseeding them with leguminous forage species With the introduction of Sirato *(Macroptilum atropurpureum)* and Banulthi *(Atylosia scarabaeoides)*, the protein level in dry hay can be increased substantially The inter-row and intra-row spaces of the grasses may be utilised by adopting suitable seed-rates of compatible species of the legumes Like grasses, the legume seeds are also turned into pellets by the tumbling action of lime so as to protect the rhizobia on them against the acidic action of soil, fertilisers and the injury due to ants, birds and rodents

Use of adequate fertilisers to boost yields

Chemical fertilisers and farmyard manure (FYM) should be used Their use will not only nprove the fertility of the soil but also its structure, increasing its waterholding capacity. he fertilisers should be applied at least once in 2-3 years, to keep up the grass species in ptimum botanical composition and at the high production level.

eeding the tree tops during lean periods

wing to their faster rate of growth during the monsoon, grazing for the livestock may be llowed mainly in the monsoon and post-monsoon periods. With the advent of winter, and wing to the lack of sufficient moisture in the soil in a readily available form, they enter lormancy. Thus, during the lean periods of spring and summer, tree tops come to the resue of the livestock-owners The young leafy, succulent material is highly nutritive and ich in crude protein and minerals. They serve as concentrate, even if fed in small quantiies along with other dried grasses and crop residues. The loppings of the trees obtained in pring and summer also may contain some substances which bring the animals quickly into he reproduction phase. Some of the important trees giving loppings and producing gum re Ku-babul *(Leucaena leucocephala)*, *Sesbania aegyptiaca* and *S.aculeata* The gum ontent in the seeds of the two species of *Sesbania* is of superior quality It may be planted n the boundaries of the fields in the cattleyard, etc., to serve as shade-cum-gum-producing lants. The spacing between the trees should be 6-8 m or even more in cattleyards, and -6 m on the bunds of the fields

ilvipastoral practices

esides the use of trees on the farm for various purposes, the trees are planted in the pasures as companion species with grasses. This practice of growing fodder-cum-fuel trees in ssociation with the grasses is popularly known as the *silvipastoral system* Under this sysem, compatible fodder trees are planted, 5-7 m apart, both ways during the monsoon. The odder from the trees is available after 4-5 years Under this system, an extra yield of the rder of 40-41 q/ha of dry grass (hay) is obtained without affecting the yield and growth of he fodder trees. For different terrains and difficult areas, some of the fodder trees that have hown promise and compatibility with the grass species are shown below in Table 16.8

able 16.8 *Commonly used trees and grasses combination*

Trees	*Grasses*
Israeli babool *(Acacia tortilis)*	Anjan *(Cenchrus ciliaris, C setigerus)*
Babool *(Acacia arabica)*	Dhaulu *(Chrysopogon fulvus)*
Siris *(Albizzia lebbek)*	Sain *(Sehima nervosum)*
Unjal *(A amara)*	Dinanath *(Pennisetum pedicellatum)*

An indicative list of the fodder trees is given in Table 16.9

ystems of fodder production

The system of fodder production varies from region to region, place to place and farmer to farmer depending upon the availability of inputs, namely, fertilisers, irrigation, insecticides, pesticides, etc , and topography An ideal fodder system is that which gives the maximum digestible nutrients per ha or maximum livestock products from a unit area It

Table 16.9 *Illustrative list of the fodder trees*

NORTH-WESTERN REGION

Acacia tortilis, A catechu A nilotica, Albizzia amara, A lebbek, Anogeissus pendula, Azadirachta indica, Capparis spinosa, Dalbergia sissoo, Grewia oppositifolia, Ficus carica, Leucaena leucacephala, Prosopis cineraria, P juliflora, Quercus incana, Q semecarpifloia, Salix tetrasperma Robinia pseudacacia, Salvadora oleoides, Dendrocalamus strictus

INDO-GANGETIC PLAIN

Acacia nilotica, Acacia tortilis, Albizzia amara, A lebbek, Adina cordifolia, Anogeissus latifolia, A pendula, Azadirachta indica, Artocarpus integrifolia, , A chaplasha, Bauhinia spp , Cassia fistula, Cordia dichotoma, Castania sativa, Dalbergia sissoo, Ehretia laevis, Syzygium cumini, Fagus sylvatica, Ficus spp , Gmelina arborea, Grewia oppositifolia, Helicteres isora, Kydia calycina, Leucaena leucocephala, Mallotus philippinensis, Millettia auriculata, Moringa pterigosperma, Morus spp , Ougeinia dalbergioides, Musa sapientum Pithecellobium dulce, Delonix regia, Quercus spp , Schleichera trijuga, Sesbania grandiflora, Terminalia spp , Tamarindus indica, Ulmus wallichiana, Zizyphus jujuba, Dendrocalamus strictus

CENTRAL ZONE

Adina cordifolia, Albizzia lebbeck, Anogeissus spp , Azadirachta indica, Artocarpus intergrifolia, Bassia latifolia, Bridelia ratusa, Bauhinia spp , Cordia dichotoma, Dalbergia latifolia, Syzygium cumini, Ficus spp , Gmelina arborea, Gliricida maculata, Hardwickia binata, Kydia calycina, Leucaena leucocephala Moringa pterigosperma Morus spp , Ougeinia dalbergioides, Pithecolobium saman, Delonix regia Pterocarpus marsupium, Terminalia spp , Zizyphus jujuba

COASTAL ZONE

Acacia tortilis, Cassia siamea, Tamarix articulata, Albizzia amara, Syzygium cumini Ficus retusa, Erythrina indica, Ailanthus malabarica

NORTH-EASTERN ZONE

Albizzia spp , Bamboos, Artocarpus integrifolia, A chaplasha Bauhinia spp Castanea sativa Desmodium spp , Fagus sylvatica, Syzygium cumini, Ficus benghalensis, F religiosa Glyricidia maculata Gmelina arborea, Moringa pterigosperma, Morus alba, Ougeinia dalbergioides, Delonix alata Terminalia tomentosa, Tinospora cordifolia

should also ensure the availability of palatable and nutritive fodder throughout the year Some of the important intensive fodder-crop rotations and the expected yields are given below in Table 16 10

Table 16.10 *Important intensive fodder crop rotation*

1	Maize+cowpea-maize+cowpea+teosinte-*berseem*+mustard (300 q/ha)-(450 q/ha)-(1000 q/ha)
2	Sweet sudan+cowpea-*berseem*+oats (1000 q/ha)-(1000 q/ha)
3	Hybrid Napier+lucerne (1250 q/ha)-(850 q/ha)
4	Maize+cowpea-*jowar*+cowpea-*berseem*+mustard (300 q/ha)-(400 q/ha)-(1000 q/ha)
5	Teosinte+*bajra*+cowpea-*berseem*+oats (1000 q/ha)-(1000 q/ha)
6	Sweet sudan+cowpea-mustard-oats+peas (1000 q/ha)-(250 q/ha)-(500 q/ha)
7	*Jowar*-turnips-oats-(1800 q/ha)

Fodder production for intensive dairy farming

The requisites for intensive dairy farming are that (i) fodder is required in uniform quantity throughout the year, (ii) the fodder crops in the rotation should be high yielding, (iii) the area of the production of fodder should be fully irrigated, and (iv) other inputs such as fertilisers and pesticides should be available in optimum quantity. The different systems of fodder production fall into two categories, viz., the overlapping cropping and the relay-cropping. In the overlapping system, a fodder crop is introduced in the field before the other crop completes its lifecycle. In relay cropping, the fodder crops are grown in succession, i.e , one after another, the gap between the two crops being very small

Intensive fodder production under overlapping system

The overlapping cropping system evolved by taking advantage of the growth periods of different species This system ensures a uniform supply of green fodder throughout the year. One such system continues for three years The best rotation in this system is. *berseem*+Japan *sarson*-hybrid *napier*+cowpea-hybrid *napier*, (October-April)-(April-June)-(June-October)

(i) In this cropping system *berseem* and Japan *sarson* seeds are mixed in the ratio of 25·2, and sown in the first week of October using a fertiliser dose of 20 kg of N and 80 kg of P_2O_5 per ha The sowing is done by broadcasting the mixed seed in the seed beds, flooded with water Care should be taken to inoculate the *berseem* seed with rhizobium culture before sowing, especially when the crop is being sown for the first time Irrigation may be given at intervals of 7-8 days, depending upon the soil and climatic conditions

(ii) The first cut from the mixture is taken in 50-55 days after sowing Japan *sarson*, being quicker in growth boosts the yields in the first cut, whereas in the subsequent cuts *berseem* takes over

(iii) Hybrid *napier* is introduced in the standing crop of *berseem* after taking the third or fourth cut from *berseem* Rooted slips are planted in February-March in lines by keeping a distance of 1 m between the rows and 30-40 cm between the plants The planting of a hectare would need about 30,000 rooted sets of hybrid *napier*. Hybrid *Napier* starts growing actively after March and should be cut 8-10 weeks after transplanting and the subsequent cuts are taken at intervals of 40-45 days After the *berseem* crop is over, a basal dose of 100 kg of P_2O_5 and 50 kg of N per ha is applied

(iv) *Berseem*, being an annual crop, completes its lifecycle in April and then the inter-row spaces of hybrid *napier* are prepared with a *desi* plough and cowpea is sown in lines, 25 cm apart In this way, in each set of two rows of hybrid *napier*, there will be two rows of cowpeas Cowpea is cut 60 days after sowing and there after hybrid *napier* does not allow any other legume to grow along with it.

(v) Hybrid *napier* continues to supply green fodder during the monsoon season At the time of the last cutting in October, the inter-row spaces are again ploughed up and the land is prepared for sowing *berseem* and Japan *sarson* to start the second cycle of the rotation

(vi) This system of intensive fodder production is economically viable only for three years After three years, hybrid *napier* is uprooted and fresh planting is taken up

This system ensures green fodder throughout the year and takes care of the dormancy period of hybrid *napier* during winter The growing of legumes enriches the soil Hybrid *napier* gets established without much care and cost. Green fodder in the first cut is increased up to 50% by Japan *sarson.*

Intensive fodder production under relay cropping

There is ample scope for increasing fodder production from the high-input areas, either by growing high-yielding fodder crops singly or in mixture The growing of three or four successive fodder crops, help to boost fodder production per unit area. Some of the important intensive crop rotations and the expected yields are summarised in Table 16.11.

Table 16.11 *Some of the cultivated fodder species for different regions*

Region	*Rainfed*	*Irrigated*
Arid tracts	*Jowar, bajra, guar, moth, lobia*	Lucerne, *berseem,*, oats, maize, *jowar, bajra*
Semi-dry	*Bajra, jowar, lobia, moth, guar*, velvet bean, field bean, *moong*	*Jowar*, maize, *lobia,*, teosinte, lucerne, *berseem, sarson,* turnips, hybrid *napier*, oats, sudan grass, Guinea grass, setaria sphacelata, rhodes
Semi-wet	Dinanath grass, *jowar, lobia,*, rice bean, velvet bean, teosinte, sunnhemp	*Berseem*, oats, sudan grass, hybrid *napier, guar, jowar,* maize, *para*, rhodes, setaria
Wet region	*Jowar*, Dinanath, rice, bean	*Berseem*, oats, hybrid *napier*, guinea, setaria, *para, jowar*
Lower hills	*Jowar, lobia, bajra,*, velvet, bean field bean, *guar*	Maize, *jowar*, oats, *berseem*, lucerne, hybrid *napier*, sudan, setaria, rhodes

Fodder production in arable farming

There is ample scope for fitting in the short-duration fodder crops, either single or in mixture, with the other crops during the gap period between two main cash crops Two distinct fallow periods are available for raising short-duration fodder crops, provided adequate resources are available In the case of the wheat-*jowar* rotation, gap periods between April and June and between October and November are available for each crop as fodder Thus, in the first rotation, M.P chari+cowpea, maize+cowpea, *bajra*+cowpea is successfully grown and an additional green fodder yield to the tune of 300-350 q/ha is obtained Similarly, in the second gap period (October-November), which is rather short, the growing of fodder turnips and short-duration mustard varieties help to get 250-300 q/ha of fodder without disturbing the normal cropping system

Fodder production under dryland farming

In these areas, the farmers usually grow atleast one crop in the *rabi* season after conserving the soil moisture Thus, there is a great scope for raising two crops under such situations The growing of a fodder crop which gets ready in 45-50 days after sowing (cowpea, *jowar, guar*, etc) yield 150-250 q/ha of green fodder After harvesting the fodder crops, such as gram, linseed, barley, wheat and safflower are raised on the conserved moisture

Suitable grass-legume mixtures

Grass legume mixture are always desirable because of their complementary functions in providing nutritive, succulent, palatable forage for the grazing animals In addition, they are capable of producing much greater quantities of digestible dry matter and protein throughout the growing season Legumes usually maintain their quality better than grasses even at maturity, and being rich in protein enhance the forage value and also add substantially the much needed nitrogen to the soil. The mixture also improves the physical condition of the soil, checks soil erosion, resists the encroachment of weeds and withstands the vagaries better than pure stands. They also help to check the spread of certain diseases and insect pests. Some of the important grass-legume mixtures are given in Table 16 12

Table 16.12 *Suitable grass-legume mixtures*

(A) *With cereal and miscellaneous fodder crops*

(1) *Maize* + (cowpea/velvet bean/teosinte/*moong*)

(2) *Jowar* + (cowpea/velvet bean/*guar*/field bean)

(3) *Bajra* + (cowpea/velvet bean/field bean)

(4) *Teosinte* + (cowpea/rice bean/velvet bean/field bean/*guar*/maize)

(5) *Oats* + (*senji/methi*/vetches/mustard/peas/*barseem*/lucerne)

(6) *Mustard* + (*barseem*/vetches/oats/lucerne/stylo)

(B) *Cultivated grasses (in assured irrigation)*

(1) *Hybrid Napier*+(cowpea/rice bean/velvet bean/*barseem*+mustard/lucerne+mustard/maize+cowpea/*barseem*+cowpea/*barseem*+oats/lucerne+oats)

(2) *Para* + (rice bean/centro/*lucerne/barseem*/cowpea/velvet bean)

(3) *Guinea* + (cowpea/rice bean/velvet bean/centro/glycine/*barseem* + mustard/lucerne + mustard/field bean/stylo)

(4) *Setaria* + (cowpea/rice bean/field bean/centro/siratro/*guar/barseem* + mustard/lucerne + oats)

(5) *Rhodes* + (centro/siratro/cowpea/rice bean/oats/mustard/*guar*)

(6) *Sudan* grass + (cowpea/rice bean/field bean/guar/velvet bean centro)

(C) *Pasture grasses*

(1) *Buffel Anjan* + (stylo/siratro/*bankulthi*/butterfly pea/field bean/*moth/guar*)

(2) *Sain* + (siratro/phasemybean/field bean/*bankulthi/guar/moth*/butterfly pea)

(3) *Marvel* + (*bankulthi*/indigofera/butterfly pea/stylo/horse grass)

(4) *Spean grass* + (siratro/stylo/*bankulthi*/butterfly pea/field bean)

(5) *Lasirus* + (rhynochosia/indigofera/field bean/*guar*)

(6) *Dinanath* + (cowpea/rice bean/field bean/*guar*)

(7) *Chrysopogon* + (siratro/stylo/butterfly pea/phasemy bean/field bean)

Estimation of fodder production

Areas under fodder production during a specified period and yield are three basic variables Yield (Y) refers to production (P) per unit area (A), during a specified period

$P = A \times Y$

$Y = P/A$

Many conditions may complicate the measurement of A, Y and P, for example

- Harvesting of crop may be spread out over a long period
- Production from forage shrubs and trees, which are spaced irregularly.
- Accidental entry of livestock in the grasslands could distort the yield in certain crops
- Grasses do not come evenly on a hilly tract due to geomorphological reasons.
- The yield (or production) to be measured needs to be based on an agreed definition Biological yield is that which is obtained before any losses during and after harvest Subtracting losses during harvesting gives the harvested yield Deducting losses during such post-harvest process like cleaning, winnowing and drying gives the economic yield
- Mixed cultivation of grasses (natural or broadcasting or differential grasses etc.) potentially can cause great confusion in measuring and reporting fodder areas, yields and production

Thus, production of grasses is a function not simply of plot area but also of plant densities in the mixture and the detrimental or beneficial interaction between the mixed fodder If areas for each fodder are presented simply as an aggregate of the areas over which that particular fodder species appear, irrespective of mixture, the resulting figures will be misleading unless supported by other information There are three alternative possible solutions

(i) Allocate the total area of different fodder species according to criteria such as the relative density in that mixture, which ensures that the sum of areas allocated to individual fodder species is the same as the total cultivated area

(ii) Allocate to each fodder species an 'imputed area' which it would have occupied in pure stand to give the same production or yield. As a result, the sum of areas allocated to fodder will not add upto the total physical area cultivated

(iii) Concentrate on only one or a few principal fodder species, and for each give separate area and production figures for pure stand and common mixtures

Accurate measurement of area under fodder production is needed when total production has to be estimated from measured yields The size of the plot under fodder cultivation could be estimated from the revenue maps Ground transact, a simple method of rapid assessment, involves dividing the study area into a grid framework derived from maps. The choice of grid size will depend upon the size of the study area, whether sampling or complete coverage is intended, the degree of homogeneity in land use patterns, the resources available, and the degree of the accuracy necessary A pre-determined point in each sequence of the grid is selected and then a fixed distance in a random direction is traversed Along this transact, observations concerning land use, fodder pattern and so on are made at regular intervals and the proportion of observation points falling under specified land use and fodder categories are calculated A variant called area sampling involves dividing the study area into natural geographic segments delineated by identifiable natural borders (ridges, roads, waterways, and so on), rather than into simple squares of equal size Point sampling involves selecting a number of points on a map or grid and recording the fodder practices at each point In many cases however, it may be necessary to undertake physical measurement of crop areas despite the complex and time-consuming nature of the task The important task in measuring an area is to transform it into an approximate polygon with straight sides and to demarcate its vertices on the ground It is essential, when using a straightline to approximate a real curving or irregular line, to balance the little pieces of the plot left out by including other small areas When only approximate data are required, especially when the area is large, enumerators may measure the boundaries of the plot by pacing. The average length of step should be calibrated. Another more accurate method/alternative is to use a graduated measuring wheel. In small scale, intensive diagnostic studies complete harvesting may avoid many biases and random errors. The yield could be calculated by using any of the following methods·

(a) *Harvesting total output*: This method could be tried where the grassland plot is small. Compared to this method, crop cutting estimates are subject to much larger sampling variability Crop cutting experiments/methods are subject to overestimation biases. They take into account only the biological yield forgetting about harvest and post-harvest losses. This method can be possible if the plots average less than 0.5 ha

(b) *Crop cutting method*: It involves identification of the plot and demarcation within it a random and specified number of subplots in accordance with specified procedures, drying the crop to standard conditions, weighing the output and computing the yield by dividing the product obtained by sub-plot area. The bias declines with increasing sub-plot size. The bias is portrayed to be negligible for sub-plot sizes of about 40-50 sq m. The tendency of sub-plots selection near the border of the plot can distort the results causing an error called 'border error'.

(c) *Sampling of harvest units* It involves a sampling of harvest, after it has been gathered at the point where it is transported for storage or disposal The enumerator visits and inspects the storage product units and obtains an estimate of the total number of these units harvested and of the estimated harvest area and selects a sample of the units to measure the average unit weight The total output is obtained by multiplying the estimated total number of units by average unit weight. It is essential and a prerequisite to gather all fodder produce in identifiable and complete units, the units should not be too variable, the fodder produce should be gathered in entirety, the entire produce should be accessible to enumerator

(d) *Beneficiaries' estimates of output*. In certain well-defined situations, carefully obtained estimates by beneficiaries regarding fodder produce can provide valid indication of the production The method can be cheap, quick and applicable on a larger scale The method involves asking a sample of beneficiaries to estimate their production in terms of either weight or number of units they normally use The survey can be pre-harvest or post-harvest. The estimates may be subject to biases which cannot be reduced by decreasing the scale of operation and increasing the level of supervision

(e) *Eye estimation* Information about fodder production may be obtained from assessments by enumerator on the basis of their eye estimates and their general familiarity with beneficiaries and the situation It can be applied on a relatively large scale at only a marginal additional cost

The production of fodder may be expressed in terms of unit (kilograms, quintals or tons) The fodder may be distributed among beneficiaries in the watershed area on·

(i) Time-sharing basis
(ii) Place-sharing basis
(iii) Produce-sharing basis

Crop residues

A large proportion of livestock subsists on the dry straw or crop residues of the cereal and other grain crops, practically throughout the year. The chief sources of the crop residues are paddy, wheat, barley, maize, *jowar, bajra* and *ragi* The straws of these crops are highly deficient in protein and some minerals, but are fairly rich in carbohydrates. Taking the advantage of high dry matter and fairly rich carbohydrates, these low-grade roughages are improved by fortifying them with suitable additives and by using suitable fodder crops.

The dry straws are also improved by the addition of suitable additives, namely, urea, minerals and water. The straws are chaffed into fine pieces (2-3 cm). One kg of urea and 1 5 kg of mineral mixture are dissolved in 20 kg of water and mixed with 97 5 kg of the chaffed material. The material in this way is stored in silo-pits like silage and is allowed to ferment under anaerobic conditions. The soluble carbohydrates present in the dry straws act as a source of energy for the bacteria to grow well After about two months, the silo-pits are opened and the material is fed to the livestock

The quality of the straws of *jowar, ragi,* wheat, paddy, *bajra*, and sugarcane trash is also improved by treating them with urea (1-2%), molasses (10-15%), salt (2%) and mineral mixture (1%) After chaffing the dry straws into fine pieces, urea, salt and mineral mixture are mixed with the chaffed material and later, sprayed with molasses and mixed thoroughly before feeding

Fodder conservation

With the availability of high fodder-yielding varieties of season-bound and perennial fodder crops, there is an excess of fodder during the peak periods of growth and scarcity during other periods The best way to regulate the supply of palatable and nutritive fodder during the lean periods of October to November and May to July is to conserve the surplus fodder in the form of hay and silage A similar situation is also experienced in the case of grassland species which essentially comprise the monsoon grasses These grasses give abundant fodder during the monsoon, but in the post-monsoon period and summer, the forage production is almost negligible owing to their dormancy with the advent of winter and acute moisture stress It becomes essential that surplus fodder should be conserved during the period of excess growth, in the form of hay, silage, etc. The need for the conservation of fodder is all the more warranted in the drought-prone areas where crop failures are frequent

Silage making

Silage is the product obtained by packing fresh fodder in a suitable container and allowing it to ferment under anaerobic conditions, without undergoing much loss of nutrients Fermentation under anaerobic condition preserves the nutritive value and enhances the keeping quality of the fodder The process of conserving green fodder in this way is termed as *ensiling*

The quality of a good silage is determined by the colour and odour of the conserved material. A good silage should be greenish or yellowish brown, with pleasant odour and should possess a high acid content On the other hand, if the silage has content of butyric acid, is yellow and emits offensive odour or has become dark brown and gives out tobacco like odour owing to heating, it is poor silage It may be palatable to the livestock, but its feeding value is very low Shephered et al (1948) have classified the silage into the following categories

1. *Very good silage*: Silage having acidic taste and odour, being free from butyric acid, moulds, showing a pH range of 3.5-4.2 and with ammoniacal nitrogen less than 10% of the total nitrogen.
2. *Good silage*: Silage having acidic taste and odour, traces of butyric acid, pH 4.2-4.5 and ammoniacal nitrogen 10-15% of the total nitrogen.
3. *Fair silage*: Ensiled material with some butyric acid , slight proteolyses, some moulds, pH 4.8 and above and ammoniacal nitrogen 20% of the total nitrogen.

Generally, the fodder crops rich in soluble carbohydrates and low to medium in protein content are ideally suitable for silage making A high content of soluble carbohydrates provides an excellent growth medium for the anaerobic bacteria to form abundant acids which increase the keeping quality of the silage. Thus, maize, *jowar, bajra,* and *napier* grass are highly suitable for making good-quality silage. On the other hand, leguminous fodder, which normally have high moisture and high crude protein and low soluble carbohydrates at the comparable stage, are not considered fit for silage making.

(a) Types of silos

Different kinds of structures, varying in design and cost, are used for silage making and storage. The size and the shape of the structure depends upon the livestock strength, soil and financial inputs available with the livestock owner. Some of the important types are briefly described below

(i) *Tower silos*: Tower silos or upright silos are among the permanent types and are relatively costly They are constructed above the ground level in the form of cylindrical towers. The diameter and height above the ground level vary according to the needs. The loss of dry matter in such silos is 5-10% only.

(ii) *PIT or trench silos*. Pit silos are less costly than the tower silos and are widely adopted for silage making They may be *pucca* or *katcha,* depending upon the climatic conditions. Pits of desired size are dug in well-drained soils. In the case of *katcha* silos, the floor should preferably be brick lined, so as to avoid contact between the chaffed material and the excessive soil moisture and easy percolation of excessive moisture from the ensiled product. In the case of such silos, when opened for feeding, a definite top layer of the silage (5-7 cm or more) is uniformly removed and fed daily

(iii) *Bunker silos*· These silos are constructed on the surface of the ground and mainly consist of two retaining walls, 2-2.5 m high, and with a slope of 2-3 cm, so as to make the silage settle tightly against them They should always be built on firm soils having good surface and sub-surface drainage.

(b) Steps for making silage

For preparing a good quality silage, the following procedure should be followed

(1) The fodder crops should be harvested and chaffed at the proper stage of growth so that the moisture, protein and carbohydrate contents are optimum for anaerobic fermentation. The carbohydrates are converted into lactic, acetic and propionic acids The early harvesting of crops affect the production of different acids, thereby reducing the storage period and affecting the quality of the silage Thus, the green fodder should have about 30-35% dry matter This is achieved by wilting the crops for certain periods before filling the silo pits, if they have excess moisture, or by sprinkling a small quantity

of water on each layer of the chaffed material, if it has less moisture.

(2) In the case of *katcha* silo pits, their bottom and sides should be carpeted with dry grass or the long straw of grasses, cereal crops, etc., so as to make a 5-6 cm thick carpet all around. This carpeting helps to prevent the direct contact between the freshly chaffed material and the soil. The direct contact between the chaffed material and the soil decreases or increases the moisture content of the ensiled material, depending upon the soil type and the water table

(3) The fodder to be ensiled should be chaffed into small pieces, preferably of the size of 1-2 cm, with the help of manually operated chaff cutter.

(4) The silo pits must be filled very quickly (say within 3-4 days) and the material must be compacted in such a way as to remove as much air as possible through constant pressing either by manual labour, or with bullocks. The exclusion of air causes fermentation under anaerobic conditions Fermentation under aerobic condition causes excessive respiration, over heating of the ensiled material and the loss of carbohydrates through the production of carbon dioxide

(5) The level of the chaffed material should be about 1-2 m above the ground level. During the course of fermentation, the material will gradually settle down

(6) Urea at the rate of 3-4 kg per ton of the chaffed material is mixed with, or sprinkled, thinly and evenly on different layers

(7) The silo pits, after filling and compacting the material carefully, should preferably be given a dome-like shape Such shape facilitates the drainage of rainwater, which otherwise would enter the ensiled material, and deteriorate the quality

(8) The ensiled material is then covered with a polythene sheet or a tarpaulin from all sides so as to protect it from direct rays of the sun and from rains

(9) After a week, the polythene sheet is removed and the material is compacted again so as to consolidate the chaffed material and remove the air to the greatest possible extent. The polythene sheet is then placed back

(10) The chaffed material ensiled by the above procedure is ready for feeding to the livestock after 2-3 months A silo pit is opened and the material is removed daily for feeding by exposing as little a surface of the ensiled material as possible. This is done mainly to prevent the direct contact of the feeding material with sun light and to prevent air-drying

(11) The feeding of the silage should be regulated in such a way that the silage is used within a reasonable period Silo pits are normally opened during a fodder scarcity Long exposure to atmospheric action may cause drying and deterioration in the keeping quality of the silage.

(12) Silage may be fed in small quantities (4-5 kg per cow) to start with and later the quantity may be increased to 15-20 kg During an acute fodder scarcity when nothing is available for feeding, silage is sufficient to meet the full requirements of the animal in respect of dry matter and essential nutrients

Hay making

Hay can be defined as the conversion of green forage into dry form without affecting the quality of the original material It can be safely stored for long periods The quality of hay largely depends on the species, the stage of harvesting and freedom from moulds and bacteria. A good-quality hay must retain a larger proportion of leaves which become brittle on drying and fall off quickly. In addition, the cured hay should have a natural green colour, pleasant aroma, optimum moisture content, freedom from moulds, etc. During hay-making, particularly in hot summer, excessive and direct exposure to sunlight should be avoided.

The efficiency and quality of hay making are determined by the moisture content in the fodder species and the ease with which moisture can be removed Thus, all the thin-stemmed grasses, namely, *anjan, sain, moshi, dhaulu, sewan, dinanath,* oat, rhodes grass, thin guinea, thin *napier,* and legumes, namely, *berseem, senji,* peas, *methi,* cowpea, field bean, rice bean and velvet bean, can be conveniently and quickly dried However, if the thick-stemmed fodder are requried to be dried quickly, they should necessarily be chaffed into small pieces or crushed by passing the materials in between rollers.

(a) Hay making structures

The most prevalent systems for hay making are as follows:

(i) *Fence method*: In this method, the fodder is cut and spread evenly and thinly over the fences of the paddocks, fields, or over specially erected fences This method helps to dry the material quickly.

(ii) *Tripod method.* In this system, tripods of convenient height are erected by using the local materials, e g., wood or galvanised iron poles. In between these poles, horizontal supports are erected to increase the carrying capacity Unchopped fodder is dried

(iii) *Gable-shaped structures*· The gable-shaped structures are made by using galvanised woven-wire fencing material of desired width and angle iron poles The fencing material is fixed in such a way as to provide a sloping support and good ventilation for quick drying This system also permits the excessive shedding of the leafy material with less handling This structure can be made economical further by using netted ropes of medium diameter and wooden poles

(iv) *Hay curing sheds* Hay curing sheds of convenient size 18 mx9 mx3 m with a slanting rod supported by pillars are constructed with corrugated asbestos This type of sheds are good for making hay during the monsoon and summer. The cost is further reduced by thatching the roof with *sarkanda* and by using wooden poles for support

(v) *Ground method* In this method, the chaffed or unchaffed material is thinly and evenly spread over a *pucca* floor so as to prevent soiling The material is turned two or three times daily till it dries completely.

(b) Steps for making hay

Good quality hay is prepared by adopting the following procedure

1 The quality of the hay is directly related to the stage of the growth of the fodder species, the leaf-stem ratio and the moisture content Thus, the fodder crops, namely, cowpea, velvet bean, *guar, jowar, bajra,* Sudan grass and oats, should be cut for hay-making at the flowering stage Pasture and the cultivated grasses are cut at 50% blossoming or slightly earlier Lucerne and *berseem* are cut for hay-making at 30-40 days intervals.

2 The fodder crops should not be harvested immediately after irrigation They should rather be harvested in the afternoon and before applying irrigation, so that they have

less of moisture and more of dry matter.

3 Though the fodder species may be dried as such, yet the best quality hay is made by chaffing the species into small pieces. The chaffed material is spread evenly in thin layers and is turned two or three times daily. In the evening, the half-dried material is collected in the form of a cone so as to prevent the exposure of the material to dew-fall at night. On the second day, the material is again spread evenly after dew has disappeared. The material is turned frequently, depending upon the climate conditions, like, the degree of sunshine, the wind velocity, and humidity. In the case of lucerene, *berseem* and cowpea, the leaves are very brittle and fall down quickly. During summer, the hay of lucerene, cowpea, etc., may preferably be made in shade so that the bleaching action may be reduced to the minimum.

4 The hay made by adopting the above steps and possessing about 15% moisture is finally transported to the hay-barn. It should retain the green colour, good aroma and flavour It should preferably be stored at a low temperature and humidity so as to prevent losses owing to the oxidation of the carbohydrates The losses may be as high as 40-50% if not stored properly.

In order to minimise the space for storage the hay is turned into bales of suitable sizes with manually-operated or power-driven hay-bales

17

Agro-Forestry Systems

Agro-forestry is defined as a sustainable land management system which increases the yield of land, combines the production of crops, including trees, and forest plants or animals or both, simultaneously or sequentially on the same unit of land and applies management practices that are compatible with cultural practices of the local population. Agro-forestry systems represent an alternative land management that can improve production in sustainable ways The adoption by the farmer would depend not only upon their potential to solve problems of a bio-physical nature, but also upon their appropriateness for the circumstances surrounding the decision makers It involves deliberately growing woody perennials along with arable crops and/or livestock seeking positive synergism

There has been a tradition of several 'agro-forestry' systems practised in our country (Tejwani, 1994) like

1. Shifting cultivation/*jhoom* cultivation,
2. Fruit trees like mangoes in semi-arid fields,
3. Zizyphus *jujuba* in both arable and grasslands of arid ecosystem,
4. Custard apple in semi-arid arable fields of Telangana,
5. *Khejri* in arid arable fields, and
6. Growing tea and coffees in the shade of trees

Agro-forestry has emerged as an appropriate technological intervention in resource-poor small farms It is an ideal system where there is scanty land, bountiful labour and less productive agriculture scenario The basic approach is a low-input land use system, sustainability, productivity, economic viability and risk minimisation Agro-forestry is a sustainable land use system which involves intimate and interacting association of agricultural and horticultural crops and woody perennials (trees, shrubs, plants, bamboos) all on the same unit of land. This form of land use has two main objective-productivity involving a multiplicity of inputs and sustainability, which implies the conservation or even improvement of the environmental aspects of the system The system may bring about restitution or improvement of soils, so as to broaden future land use options (Plate 46 a, b)

Plate 46 (a, b) *Encouraging agro-horticulture and farm-forestry helps in extra-income generation. Farm forestry reduces pressure for fuel wood and fodder on CPRs*

The unit of land management is a watershed or a part of watershed and emphasis is laid on trees/shrubs/grasses that will protect the land as well as produce fodder, fuelwood, fruits, etc. A major focus has been put, especially in last few years in developing countries, on agro-forestry. It is necessary to identify multipurpose trees (MPTs) with two or more uses (fuel, fodder, foliage, food, fruit, timber or industrial raw materials). In India, due to paucity of fuelwood and fodder, emphasis should be specifically on MPTs with fuelwood and fodder production.

Field crops like pearl millet, legumes and oilseed crops in a field predominated by Khejri (*Prosopis cineraria*) and Ber (*Zizyphus spp*) is an example of traditional agro-forestry in northern pockets of India. Impairment of the ecosystem can be avoided, yields increased and crops diversified by reasonable and judicious combination of tree plantations with agricultural crops and/or cattle farming.

The maintenance of forest vegetation, in certain pockets of watershed areas, could be helpful for soil and water conservation. Silvicultural and scientific forest management practices help in controlling soil erosion and maintaining moisture. The ideal method for soil conservation is through modern systems of forest working (selection system of felling). Individual trees, as they reach maturity, or utilisable dimensions, are selected and removed annually No area of the forest is cut as such and species without utilisation value are not felled at all, except in the interest of security and regeneration of the valued species. Besides, the correct method of removing the old crop and replacing it should be followed and permanent damage to soil should be avoided.

Objectives of agro-forestry

(a) *Biomass production*· The maximum production of biomass per unit area in time is the primary objective of agro-forestry systems in the watershed areas

(b) *Soil conservation*· Compared to the permissible limit of soil loss 4.5 tons/ha/year, the average soil displaced is around 16 tons/ha/year. Wasteland, especially sloping terrain, should be treated through agro-forestry in watershed programme

(c) *Soil improvement*: Agro-forestry practices enrich soil by nitrogen fixation and addition of organic matter Agro-forestry helps in meeting nutrient requirement of plants growing in association with trees and at the same time, the soil structure and infiltration rates are also improved.

(d) *Agro-based village industries* Agro-forestry in watershed areas help in promotion of agro-based industries like herbal drugs, poultry, piggery, dairy, bee-keeping, sericulture, mushroom cultivation, etc

(e) *Moderation of micro-climate*. The micro-environs in the neighbourhood of trees is moderated by adopting an agro-forestry programme The field crops in vicinity of trees receive multidirectional effects and benefits. The impact is more prominent in arid and semi-arid zones.

Important agro-forestry models

Few models of agro-forestry system are already popular among the farmers in different parts of the world It is worthwhile considering these models

(a) *Acacia albida model in Africa* This is the most traditional farming system of Africa, where the farmers generally nurse the naturally grown plants in the field The presence of *Acacia albida* trees improve crop yield On a plot, crop yields under the tree canopy are significantly higher than on open areas This practice exists even now The advantage of this species is the natural defoliation during the rainy season when the crops are growing Generally, 50-100 trees are maintained per ha under this system

(b) *Prosopis cineraria model in Rajasthan*: Maintaining *Prosopis cineraria* commonly known as 'Khejri' tree, is a traditional practice in Rajasthan and adjoining areas in the north-west India. Khejri trees grow on their own in Rajasthan and the farmers maintain them, lopping their branches from time to time for fodder and fuel Generally, 50-100 trees are maintained in tree and bush forms.

(c) *Gliricidia livehedges model. Gliricidia* is leguminous fodder tree, which was introduced in Asia long back and was promoted in India as green manure crop. The recommendation was to establish live hedges on the paddy fields and to use top foliage as green manure This system is also popular in many parts of India and being a legume it enriches the soil and coppices very well. *Gliricidia* has a wide range of adaptability from partly waterlogged paddy field bunds to drought-prone areas and has multiple uses as fodder, fuelwood and green manure

(d) *Shelterbelt model in China* One of the best models of agro-forestry in the form of shelterbelt has been adopted on most of the farms in China The agricultural fields were developed into 25 ha blocks and 2-3 lines of trees were established all around the blocks These shelterbelt blocks help in soil and moisture concentration and protect the crop from sunlight and high speed winds. The sale of timber generates substantial income to the farmers and local community .Most important fast growing tree species used for establishing shelterbelt are Poplars, Taxodium, Paulownia, Chinese Fir, Pines and Casuarina Generally, a spacing of 3x2 m is maintained to develop a thick row of trees The trees are thinned in 2-3 stages, depending on the species and rate of growth

(e) *Paulownia alley cropping* In addition to the shelterbelt planning, *Paulownia* has been introduced for alley cropping in central parts of China. *Paulownia tomentosa* or *Paulownia elongata* are planted at 5x20 m spacing and grow soyabean, beans, maize in rainy season followed by wheat in winter The system helped to raise the foodgrain yield of 6-8 tons/ha This model has been popularly adopted on over 2 5 m ha in China during the last decade

(f) *Poplars in India* Alley cropping with 400-600 plants of *Populus deltoides* in wheat growing areas, on latitude above 30° N, with deep loamy soil and adequate groundwater has been adopted by a large number of farmers in Uttar Pradesh, Haryana, Himachal Pradesh and Punjab. This is one of the few models where the system generates cash income for the farmers

(g) *Eucalyptus as shelterbelt in north India* The farmers in Punjab, Haryana and western UP have planted *eucalyptus* on their farm bunds and road sides on a large scale. While *eucalyptus* hybrid covers 90% of the trees on shelterbelts other species grown are *Dalbergia sissoo, Populus deltoides and Bombax ceiba* The Forest Research Institute based on their research studies and on-farm data has reported that the performance of *Eucalyptus* is good under shelterbelt planting where the soil depth is more than 2 m and the spacing provided between the tree is 1 5 m or more *Eucalyptus* trees neither compete with arable crops for moisture nor exhibit allelopathic effects, when adequate moisture is available in the field. In most parts of Punjab, Haryana and Uttar Pradesh, excess of sub-soil water is a problem and hence *eucalyptus* is a boon for them. Lack of marketing facilities can be a setback of large-scale propagation of *Eucalyptus*

(h) *Calliandra, leucdaena and sesbaina hedges*: *Calliandra* is a very popular hedge in Indonesia and *Leucaena* is popular in Philippines and Hawaii. *Leucaena* and *Callindra* have the potential to produce timber by modifying the management While *Gliricidia* is preferred as green manure, foliage of the other two species is popular as fodder. *Sesbania sesban* is another fast growing legume very popular in western India, particularly in irrigated sugarcane fields *Sesbania* plants can be harvested within 1-2 years for fuel, fodder and minor timber.

(i) *Melia model in western Maharashtra*: *Melia azedarach* (Bakayan) is less known for its performance and uses in many parts of India. Farmers in western Maharashtra have traditionally explored the possibility of using the poles of 3-6 year *Melia* trees for housing and many other purposes. Generally, *Melia* is planted at a close distance in a single row on field bunds, preferably along the water channels by direct sowing of seeds. To maintain the main stem straight, side branches are pruned regularly and used as fodder for livestock This would also help in reducing the shade on the arable crops. At the end of 3-4 years, when the basal diameter of the main stem reaches 8-10 cm, farmers harvest the poles and allow coppicing. The poles are mostly used for rural housing.

(j) *Thespesia in paddy fields*: Farmers in the foothills of Western Ghats have been growing *Thespesia populnea,* locally known 'Bhendi' on the bunds of paddy fields as well as on other available space and pollarading regularly at an interval of three years to harvest poles Generally, a tree would produce 30-40 new shoots and on an average about 25-30 poles are harvested from each tree. *Thespesia* can be grown in a wide range of agro-climatic conditions.

(k) *Leucaena for fodder, fuel and timber*: This is a new model introduced recently in many states in South India through social forestry programmes Farmers are advised to plant *Leucaena* seedlings on field bunds and manage as trees for fodder, fuel and poles This model is picking up in many irrigated areas, where protection from stray animal is provided Farmers having dairy animal prefer to maintain *Luecaena* as fodder bushes Systematical promotional efforts with authentic field data would help to popularise this model on a large scale.

Selection of tree species

The selection of tree species should be such that the cultivation of crops traditionally grown is not changed due to new agro-forestry system Initially, mostly tree species were selected on their income-generating abilities Later, consistent arable crop may be adopted But, such hastiness in planning may affect the micro-climate adversely. The shift from traditional farming to agro-forestry should be slow and gradual

The production level of the arable crops should be maintained at any cost Following criteria should be adopted and considered as regards the selection of plant species

- — Easy establishment
- — Fast growth and short gestation period

- Non-interference with arable crops
- Non-allelopathic effects on arable crops
- Ability to fix atmospheric nitrogen.
- Easy decomposition of litter.
- Ability to withstand frequent lopping.
- Ability to generate employment.
- Multiple uses and high returns.

None of the existing species have all the aforementioned qualities PIAs may provide scores to each species on these qualities The scoring matrix, so created, would describe the community preferences objectively

Table 17.1 *List of multipurpose tree species*

(a) *Fodder-cum-fuelwood species*
  1 Subabul *(Leucaena leucocephala)*
  2 Gliricideia *(Gliricidia sepium)*
  3 Agastya *(Sesbania grandiflora)*
  4 Shevari *(Sesbania sesban)*
  5 Corol tree *(Erythrina sp)*
  6 Bhendi *(Thespesia populnea)*
(b) *Fuelwood and timber species*
  1 Ramkathi Babul *(Acacia nilotica)*
  2 White siris *(Albizia procera)*
  3 Siris *(Albizia lebbeck)*
  4 Neem *(Azadirachta indica)*
  5 Casuarina *(Casuarina equisetifolia)*
  6 Kassod *(Cassia siamea)*
  7 Shishum *(Dalbergia sissoo)*
  8 Pongamia *(Deris indica)*
  9 Bakain neem *(Melia azedarach)*
  10 Horse bean *(Parkinsonia aculeata)*
  11 Madras thorn *(Pithecellobium dulce)*
  12 Khejri *(Prosopis cineraria)*
  13 Bamboo *(Dendrocalamus strictus)*
(c) *Softwood and pulpwood species*
  1 White Albizia *(Albizia facataria)*
  2 Poplar *(Populus deltoides)*
(d) *Fruit and vegetable species*
  1 Ramphal *(Annona recticulata)*
  2 Custard apple *(Annona squamosa)*
  3 Indian gooseberry or Amala *(Emblica officinalis)*
  4 Drumstick *(Moringa oleifera)*
  5 Ber *(Ziziphus mauritiana)*

Table 17.2 *Tree species for different sites*

(a) *Cold hilly regions*
1 Silver oak *(Grevillea robusta)*
2 Black wattle *(Acacia mearnsii)*
3 Black locust *(Robinia pseudoacacia)*
4 Alder *(Alnus nepalensis)*
5 Poplars *(Populus euroamericana, Populus tomentosa)*
6, Willows *(Salix sp)*
7 Paulownia *(Paulownia tomentosa)*

(b) *Heavy rainfall and high water table areas*
1 Bamboo *(Dendrocalamus strictus)*
2 Arjun *(Terminalia arjuna)*
3 Eucalyptus *(Eucalyptus grandis)*
4 Bhendi *(Thespesia populnea)*
5 Pongamia *(Deris indica)*
6 Sesbania *(Sesbania sesban)*
7 White siris *(Albizia procera)*
8 Casuarina *(Casuarina equisetifolia)*

(c) *Dry areas*
1 Babul *(Acacia nilotica)*
2 Neem *(Azadirachta indica)*
3 Kassod *(Cassia siamea)*
4 Ber *(Zizyphus mauritiana)*
5 Custard apple *(Annona squamosa)*
6 Horse bean *(Parkinsonia aculeata)*
7 Khejri *(Prosopis cineraria)*

(d) *Well-managed irrigated areas*
1 Drumstick *(Moringa oleifera)*
2 Melia *(Melia azedarach)*
3 Shishum *(Dalbergia sissoo)*
4 Subabul *(Leucaena leucocephala)*
5 White siris *(Albizia procera)*
6 Gliricidia *(Gliricidia sepium)*
7 Sesbania *(Sesbania sesban)*
8 Casuarina *(Casuarina equisetifolia)*

Priority for selection of species

Although the above species are good for agro-forestry, one particular site may not accommodate more than 2-3 species, as per the choice of the farmers Adaptability of the species to the site is the main criteria, without which the entire plan may fail. It is easy to group the species based on the agro-climatic conditions However, the above list depict mostly the tropical species except the species recommended for high altitudes The other components of climate affecting the species selection are soil moisture, soil depth and soil pH

Based on the water availability, the sites can be classified into three categories as under·

1. Waterlogged or high water table areas
2. Adequate moisture supply areas
3. Moisture scarcity areas

According to the type of soil pH the sites can be classified into the following categories·

High acidic	pH below 4 5
Acidic	pH between 4 5 and 6 5
Neutral	pH between 6 5 to 7 5
Alkaline	pH between 7 5 to 8 5
Alkali	pH above 8 2, with high Na ions
Saline	pH below 8 2, with soluble salts of Na, Ca and Mg

Depending upon the soil texture and depth, they can be classified among the following groups

1. Sandy soils
2. Well-drained loamy soils
3. Deep, clay soils
4. Shallow gravely soils

and many other sub-groups

After screening the species to suit the above agro-climatic conditions, the next aspect is profitability. Ideally, the agricultural scientists want the tree crop not to affect the arable crop But in reality, farmers want to earn higher total returns and certainly do not mind sacrificing a portion of the foodgrain production. As profitability is the function of production level and price, which involves some assumptions and risk of marketing the produce, rich farmers are able to take bold decisions

Following are the beneficial aspects of trees in tree-crop-soil-water system

1. Enrichment of carbon and nitrogen
2. Reduction in soil erosion and nutrient loss
3. Siphoning of nutrients from lower layers to the surface
4. Improvement in litter quality
5. Increased microbial activity.
6. Improvement of physical properties of the soil profile
7. Fixation of mobile sand dunes.
8. Work as shelterbelt/wind break
9. Best moderator in recovering several types of wastelands
10. Nullify acidity, alkalinity and water-logging for other crops

Potential beneficial effects of trees on soil is summarised in the Table 17 3

Preferred tree species suitable for sandy/duney soils, saline/alkaline soils are shown in

Tables 17.4 and 17.5 Preferred timber/fuelwood trees species for agro-forestry are shown in Table 17.6.

Table 17.3 *Summary of the potential beneficial effects of trees on soil*

Nature of processes	*Processes*	*Main effect on soil*
Input processes (augment additions to the soil)	Biomass production	Addition of carbon and its transformation
	Nitrogen fixation	N-enrichment
Output process (reduce losses from the soil)	Protection against water and wind erosion	Reduce loss of soil as well as nutrients
Turnover processes	Nutrient retrieval/cycling/release	Uptake from deeper layers and 'deposition' on surface via litter
		Withholding nutrients that can be lost by leaching
		Timing of nutrient release this can be regulated by management interventions
Catalytic processes (indirect influences)	Physical processes	Improvement of physical properties (waterholding capacity, permeability, drainage, etc) at the microsite as well as at watershed (macrosite)
	Root growth and proliferation (enhanced)	Addition of (more) root biomass, growth-promoting substances microbial associations
	Litter quality and dynamics	Improvement of litter quality through diversity of plant species, better timing of quantity, and method of application of litter possible
	Micro-climatic processes	Creation of more favourable micro-climate shelterbelt and winderbreak effects
	(Bio) chemical/physical/biological processes	Moderating effect on extreme conditions soil acidity, alkalinity, water-logging, etc

Table 17.4 *Tree species suitable for shallow, rocky soil and sandy, duney soils*

	Suitable for shallow, rocky soil		*Suitable for sandy, duney soil*
1	*Acacia holosericea*	1	*Acacia albida*
2	*Acacia leucophloea*	2	*Acacia anema*
3	*Acacia salicina*	3	*Acacia ferruginea*
4	*Acacia senegal*	4	*Acacia holosericea*
5	*Anacardium occidentale*	5	*Acacia leucophloea*
6	*Annona squamosa*	6	*Acacia salicina*
7	*Azadirachta indica*	7	*Acacia senegal*
8	*Balanites aegyptica*	8	*Acacia tortilis*
9	*Boswellia serrata*	9	*Balanites aegyptica*
10	*Butea monosperma*	10	*Borassus flabellifera*
11	*Capparis decidua*	11	*Boswellia serrata*
12	*Cassia siamea*	12	*Butea monosperma*

Contd

Table 17.4 *Contd*

13	*Celtis australis*	13	*Capparis decidua*
14	*Cordia obliqua*	14	*Cassia siamea*
15	*Dendrocalamus strictus*	15	*Casuarina equisetifolia*
16	*Dichrostachys cineraria*	16	*Colophospermum mopane*
17	*Eucalyptus tereticornis*	17.	*Dalbergia sissoo*
18	*Grewia tenax*	18	*Dichrostachys cineraria*
19	*Hardwickia binata*	19	*Hardwickia binnata*
20	*Holoptelia intergrifolia*	20	*Moringa oleifera*
21	*Madhuca latifolia*	21	*Morus alba*
22	*Parkinsonia aculeata*	22	*Phoenix dactylifera*
23	*Pithecellobium dulce*	23	*Prosopis cineraria*
24	*Pongamia pinnata*	24	*Prosopis juliflora*
25	*Prosopis juliflora*	25	*Salvadora oleoides*
26	*Phus mysoreusis*	26	*Tamarix aphylla*
27	*Wrightia tinctoria*	27	*Tecomella undulata*
28	*Zizyphus nummularia*	28	*Zizyphus nummularia*

Table 17.5 *Tree species suitable for saline and alkaline soil*

	Suitable for saline soil		*Suitable for alkaline soil*
1	*Acacia aneura*	1	*Acacia aneura*
2	*Acacia holosericea*	2	*Acacia nilotica*
3	*Acacia salicina*	3	*Acacia salicina*
4	*Annona squamosa*	4	*Acacia tortilis*
5	*Balanites aegyptica*	5	*Albizia lebbek*
6	*Butea monosperma*	6	*Balanites aegyptica*
7	*Capparis decidua*	7	*Butea monosperma*
8	*Cassia siamea*	8	*Capparis decidua*
9	*Casuarina equisetifolia*	9	*Casurina equisetifolia*
10	*Colophospermum mopane*	10	*Colophospermum mopane*
11	*Dalbergia sissoo*	11	*Dalbergia latifolia*
12	*Ficus bengalensis*	12	*Emblica officinalis*
13	*Moringa oleifera*	13	*Eucalyptus camaldulensis*
14	*Phoenix dactylifera*	14	*Ficus bengalensis*
15	*Pongamia pinnata*	15	*Leucaena leucocephala*
16	*Prosopis cineraria*	16	*Madhuca latifolia*
17	*Prosopis juliflora*	17	*Pithecelobium dulce*
18	*Salvadora persica*	18	*Pongamia pinnata*
19	*Tamarindus indica*	19	*Prosopis cineraria*
20	*Tamarix aphylla*	20	*Prosopis juliflora*

Contd

Table 17.5 *Contd*

21	*Tecomella undulata*	21	*Salvadora persica*
22	*Ziziphus mauritiana*	22	*Tamarindus indica*
23	*Ziziphus nummularia*	23	*Tamarix aphylla*
		24	*Tecomella undulata*
		25	*Terminalia arjuna*
		26	*Zizyphus mauritiana*
		27	*Zizyphus nummularia*

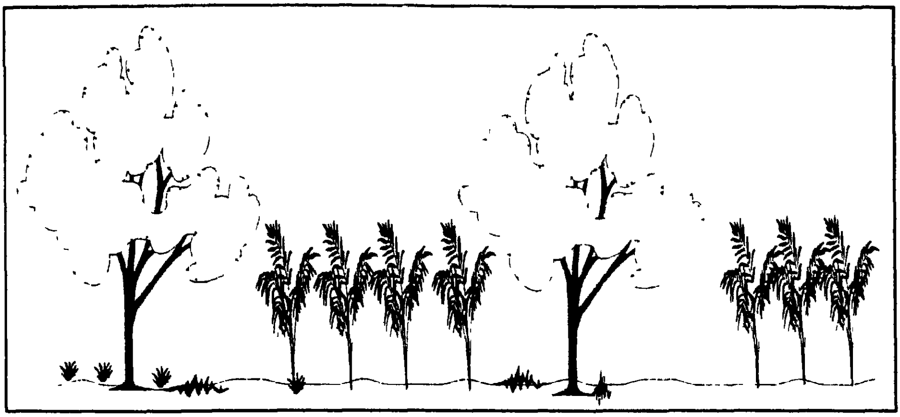
Table 17.6 *Prefered timber trees and fuelwood trees*

	Preferred timber trees		*Preferred fuelwood trees*
1	*Santalum album*	1	*Acacia nilotica*
2	*Dalbergia latifolia*	2	*Prorcspis juliflora*
3	*Dalberiga sissoo*	3	*Zizyphus mauritiana*
4	*Tecomella undulata*	4	*Tamarindus indica*
5	*Morus alba*	5	*Hardwickia binata*
6	*Borassus flabellifera*	6	*Leucaena leucocephala*
7	*Acacia nilotica*	7	*Prosopis cineraria*
8	*Hardwickia binnata*	8	*Santalum album*
9	*Tamarindus indica*	9	*Cassia fistula*
10	*Prosopis cineraria*	10	*Cassia siamea*
11	*Acacia tortilis*	11	*Acacia sengal*
12	*Syzygium cumini*	12	*Acacia tortilis*
13	*Eucalyptus camaldulensis*	13	*Anogeissus pendula*
14	*Terminalia alata*	14	*Boswellia serrata*
15	*Terminalia arjuna*	15	*Madhuca lalifolia*
16	*Terminalia bellerica*	16	*Melia azedirach*
17	*Phoenix dactylifera*	17	*Ongeinia oojeinesis*
18	*Diospyros melanoxylon*	18	*Pongamia pinnata*
19	*Prosopis juliflora*	19	*Albizia amara*
20	*Zizyphus mauritiana*	20	*Syzygium cuminii*
21	*Leucacna leucocephala*	21	*Acacia albida*
22	*Madhuca lalifolia*	22	*Eucalyptus camaldulensis*
23	*Ongeinia oojeinensis*	23	*Acacia auriculiformis*
24	*Acacia albida*	24	*Casuarina equisetifolia*
25	*Eucalyptus tereticornis*	25	*Albizia lebbek*
		26	*Butea monosperma*
		27	*Terminalia alata*
		28	*Terminalia arjuna*
		29	*Terminalia bellerica*

Tree density in agro-forestry systems

After selecting the tree species, another important component to be decided for the system is the number of trees to be established per unit area. From the conservation point of view, the number of trees should be such that they would not drain out the productivity of the soil and the land should be in a position to facilitate optimum growth of tree species (see Figure 17.1). Under any agro-forestry system, larger the area under trees, higher is the soil fertility. If one plot is used for growing trees and the other for crops, the fertility status of the tree plot will reach the maximum, while the arable crop plot will lose the productivity in the long run. Wastelands, in a watershed area, can be brought under woodlot to meet the fodder, fuel, timber, and fibre needs In agricultural land, the aim should be to increase food production through useful intervention of trees. The aim should be to restrict the tree area at a level that would not drop the arable crop yield beyond 20%.

Figure 17.1 *Inter-planting*



The two main types of tree arrangements are alley cropping and zonal agro-forestry system In alley cropping, several trees are laid out with tree and hedge rows at regular intervals, varying from 3 to 20 m in the field maintained under intensive crop management practices. If trees are planted in an unplanned manner, they can hamper tillage operations In the absence of adequate level of soil moisture, arable crops are severely damaged due to the competition for moisture. The value of the produce varies with the location and the end use In India, alley cropping means, more or less, planting of trees on field bunds These trees do not hinder the tillage operations and serve as shelterbelts and do not cover larger part of the farming area.

The number of trees to be planted per unit area is also dependent on the canopy size of the species selected for planting. Trees having wider branches will have to be planted at a wider distance and in smaller numbers, while species having narrow branching habits can be planted at a closer distance. Competition for the soil moisture by the trees and arable crops is an important issue to be taken into consideration while introducing agro-forestry. Of the total available moisture in the soil only 5-8% is utilised by the trees while the remaining 90% is wasted Plants species can be classified into three groups based on their physiological requirement (see Table 17.7):

Table 17.7 *Classification of plant species based on physiological requirement*

C-3 plants (less efficient in water utilisation)	*Cu Plants (more efficient in water utilisation)*	*CAM Plants (most efficient)*
Soyabean, rice, cotton, eucalyptus groundnut, carrot, bean, *datura*, wheat, barley, oat	Maize, sorghum, napier grass, sugarcane, sudan grass, blue panicum	Pineapple, agave, cactus, etc

Agro-forestry systems

Many indigenous and appropriate agro-forestry systems are prevalent in different agro-ecological regions of India Some of them are discussed as under:

Shifting cultivation

This is an age-old practice which is essentially prevalent in north-eastern states and Madhya Pradesh, Orissa, Andhra Pradesh, Bihar, etc The areas under shifting cultivation in certain states are given in Table 17 8.

Table 17.8 *Area under shifting cultivation*

States	*Area (million ha)*	*% Area under shifting cultivation*
N-E states	2 70	16 9
Orissa	2 60	53 2
Andhra Pradesh	0 15	5 0
Madhya Pradesh	0 12	1 3
Bihar	0 08	1 6s

Shifting cultivation consists of cultivation of crops on steep slopes of hills and hillocks, etc , by clearing certain trees, shrubs, bushes, etc., upto the stump level during winter The cut-and-fell materials are left for drying and these are burnt to make the land ready for sowing different crops before the rains After two or three years, this area is abondoned and a new site is selected This system of cultivation is mostly applied in tropical to sub-tropical climatic areas with high rainfall and high humidity Forest prevalent in such areas are tropical evergreen, temperate evergreen, conifer and pine forests This system is very labour-intensive and requires small quantities of inputs and capital The number of years before a community returns to the same patch of land will depend on the land available to the community and its population Yields of crops decline with reduction in cycle time In Abhujmarh area of Bastar district in Madhya Pradesh, the land of primitive tribe group 'Abhujmarias', where the population is only around 28,000 and the area (neither declared forest nor revenue land in government records) is around 8000 sq km In Abhujmarh, family returns back to the same plot of land after 40-50 years The cycle has come down to 5-7 years in most other parts of India Variety of crops can be taken up when the cycle is long (8-15 years) Emphasis is given on growing maize, leafy vegetables, coarse grains and tuber crops in areas where the cycle is shorter.

In short, the practice of shifting cultivation involves cutting down the vegetation on hill slopes (say 20-40%), allowing the cut vegetation to dry and burn, cropping the land for 1-2 years and then abandoning the area and moving to a newer site In the process, there is considerable soil loss and runoff (see Table 17 9)

Table 17.9 *Effect of shifting cultivation on soil loss and runoff*

	Shifting cultivation	*Agriculture with bench terracing*
Soil loss (tons/ha)	40 9	2 3
Runoff (mm/yr)	114	95
Runoff (%)	7 0	5 8

Due to above mentioned reasons, the shifting cultivation should be controlled and regulated either to abolish it or, if not possible, then modify it The indiscriminate cleaning of slopes should be prohibited and no land with more than 20% slope should be cleared for the purpose On milder slopes clearing and temporary cultivation, in conjunction with raising forest tree crops may be allowed The management should be so ascertained that every year regenerated (abondoned) area is absorbed back in to the forest and equivalent area may be made available for cleaning and further cultivation In no situation, shifting cultivation should return to the same site again till a regenerated forest has fully taken possession of the land .

Trees like Alder (*Alnus nepalensis*) may be grown at the rate of 60 trees/ha in areas where above measures are impractical to implement Such trees are either pollarded or coppiced after six years to take arable crops Subsequent cutting can be done after every four years Ideally, administration and policy makers should strive to abolish shifting cultivation altogether

Toungya

This is a system of establishing commercial forest plants in which agricultural crops are grown on a temporary basis in between the rows of the tree species This system perhaps started in North Bengal It is referred to as 'Kumari' cultivation in South India This system is also prevailing in many other states, like Kerala, Tamil Nadu, Uttar Pradesh, Orissa, Andhra Pradesh, Karnataka and N-E regions.

The land is prepared and tree planting is done Agricultural crops are cultivated for one to three years and then the same cycle is repeated in certain other areas In certain areas, crops are grown one year prior to the plantation of the trees The land usually belongs to the forest department and arable farming is done by selected farmers Department establishes the tree plantation and the cultivators, besides using intervening area for cultivation, provide the labour to take care of the plantation All the inputs for crop production are provided by the farmers This system is beneficial to forest department and BPL landless families This system may be in favour of exploitative farmers , if a fair deal is not provided to them. The forest department in Kerala auctions land for such purpose The practice of *Taungya* or *Kumari* is gradually declining The present area under *Taungya* is only about 10,000 ha in India Similar approach is recommended for community wasteland development in the semi-arid Aravalli hills in Rajasthan Such a system, could easily be adopted in ongoing forestry programmes like JFM.

The most profitable *Taungya* practice is cultivation of crops in teak (*Tectona gradis*) plantations. In the coastal areas of Andhra Pradesh and Orissa, groundnut cultivation is carried out in cashewnut plantations In the high hills of Tamil Nadu and Kerala initial cash crop potato is followed by plantations of *Eucalyptus globulus, Acacia mearnsil*, etc The system of *Taungya* has effectively been used by large commercial farmers in irrigated areas of Terai region of Uttar Pradesh for establishing *Poplar* plantation The decreasing and declining practice of *Taungya* system may be promoted in its right spirit. Tree spacing in *Taungya* system of agro-forestry depends on the type of tree and their purpose/utility.

(a) Tall, widespreading tree species (*Mango, Jamun, Neem*) = 6x6 m to 10x10 m.
(b) Multipurpose tree species (Bamboo, *Jungle jalebi* etc.) = 5x5 m
(c) Fuel and timber trees (*Subabul, Casurina*) 2x1 m to 3x3 m.
(d) Small bushes (*Agave*) = 25-30 multirow spacing

Silvipastoral system

Such systems are most ideal in wastelands, wherein, trees are associated with grasses/fodder legumes. These systems involve lopping trees and grazing understorey grasses and bushes in forest land plantations. Energy plantations may be taken up with fodder and forage crop cultivation. This system caters to the two basic needs of watershed beneficiaries—fodder for cattlehead and fuelwood This system has a potential application in vast areas of cultivable wasteland and marginal forest land. Village commons (common or community land) and privately owned degraded wastelands may be adopted for this system Recommended multitier silvipastoral tree-shrub-grass combinations for different agro-climatic regions are given below in Table 17 10.

Table 17.10 *Suitable multitier silvipastoral combinations for different agro-climatic regions*

(1) Temperate and Humid Western Himalayan Region	
Trees	*Populus ciliata, Quercus dilatata Q incana Salix alba, Robinia pseudacacia, Morus nigra, Celtis australis, Grewia oppositifolia, Albizzia amara, A procera, A lebbek, Acacia catechu, Ficus carica*
Shrubs	*Grewia oppositifolia Leucaena latisiliqua Dichrostachys nutens, Bauhinia sp , Sesbania sesban*
Grasses and Legumes	*Themeda anathera, Chrysopogon fulvus, Arundinella nepalensis, Heteropogon contortus, Cenchrus ciliaris Setaria anaps, Phaseolus atropurpureus, Stylosanthes hamata, Phleum pratens, Muhlenbergia duthieana, Poa pratensis, Dactylis glomerata, Medicago sp , Trifolium subterranueum*
(2) Humid Bengal-Assam Region	
Trees	*Azadirachta indica, Dalbergia sissoo, Emblica officinalis, Peltophorum pterocarpum Pithecellobium dulce, Pongamia pinnata, Albizzia lebbek, A stipulata, Artocarpus heterophyllus Bauhinia sp , Moringa oleifera, Morus alba, Syzygium cumini, Tamarindus indica, Eucalyptus sp*
Shrubs	*Leucaena latisiliqua, Sesbania grandiflora, S sesban, S microcarpa, Bauhinia sp Desmantheus virgatus*
Grasses and Legumes	Setaria anceps, Pennisetum pedicellatum, Panicum antidotale, Chrysopogon aciculatus, Marenga porphyrocoma, Panicum notatum, Arundinella bengalensis, Atylosia scaraboides, Desmodium uncinatum, Puereria thunbergiana, Clitoria terneata, Vicia sp , Glycine javanica, Stylosanthes hamata

Contd.

Table 17.10 *Contd*

(3) Humid Eastern Himalayan Region and Islands	
Trees	*Eucalyptus globulus Pongamia pinnata, Quercus semicarpifolia Salix tetrasperma, Albizzia chinensis, Artocarpus heterophyllus, Bauhina sp, Moringa oleifera, Morus serrata, Syzygium aqueum, Populus ciliata*
Shrubs	*Desmodium cephalotus, Leucaena latisliqua, Sesbania grandiflora, S sesban, Desmanthes virgatus*
Grasses and Legumes	*Setaria anceps*
(4) Sub-Humid Sutlej-Ganga Alluvial Plains	
Trees	*Acacia nilotica, A tortilis, Anogeissus latifolia A pendula, Azadirachta indica, Dalbergia sissoo, Morus alba, Pithecellobium Dulce, Pongamia Pinnata, Zizyphus mauritiana Ailanthus excelsa, Albizzia lebbek, A pocera, A amara, Bauhina variegata, Cordia dichotoma, Hardwickia binata, Gmelina arborea, Moringa oleifera, Adina cordifolia, Morus alba*
Shrubs	*Leucaena latisiliqua, Sesbania grandiflora, S sesban, Dichrostachys nutens, Desmanthes virgatus Desmodium diffusum, D cephalotus*
Grasses and Legumes	*Cenchrus ciliaris, C setigerus, Chrysopogon fulvus, Setaria anceps, Dichanthium annulatum, Isilema laxum, Sehima nervosum, Panicum antidotale, Clitoria terneata, Macroptelium atropurpureum, Stylosanthes hamata, Phaseolus calcaratus Desmodium uncinatum*
(5) Sub-Humid/Humid Eastern and South-Eastern Upland Regions	
Trees	*Acacia nilotica, Anogeissus latifolia, Azadirachta indica, Cordia dichotoma Dalbergia sissoo Delonix elata, Emblica officinalis, Grevillea robusta, Hardwickia binata Pithecellobium dulce Pongamia pinnata, Zizyphus mauritiana, Ailanthus excelsa, Albizzia chinensis A lebbek A amara, Artocarpus heterophyllus, Bauhinia purpurea B variegata Moringa oleifera Morus alba Glyricida maculata*
Shrubs	*Leucaena latisiliqua, Desmanthes virgatus, Sesbania grandiflora S sesban Desmodium sp*
Grasses and Legumes	*Dichanthium annulatum, Isilema laxum, Setaria anceps Panicum antidotale Chloris gyana Chrysopogon fulvus Eremopogon faveolatus Atylosia scaraboides Macroptelium atropurpureum Stylosanthes hamata, S gracilis, Clitoria terneata, Cenchrus ciliaris, Sehima nervosum*
(6) Arid Western Plain	
Trees	*Acacia tortilis, Azadirachta indica, Cordia rothii, Hardwickia binata, Morus alba Parkinsonia aculeata, Pithecellobium dulce, P seman, Salvadora oleoides Tamarix sp Zizyphus mauritiana Alianthus excelsa, Albizzia lebbek, Moringa oleifera, Tecomella undulata Eucalyptus sp Prosopis cineraria, P juliflora*
Shrubs	*Dichrostachys nutens, Leucaena latisiliqua, Capparis decidua, Sesbania sesban*
Grasses and Legumes	*Cenchrus ciliaris, C setigerus, Lasirus sindicus, Dichanthium annulatum Cymbopogon juraneusa Panicum antidotale, Marcroptelium atropurpureum Desmodium triflorum*
(7) Semi-Arid/Lava Plateaus and Central Highlands	
Trees	*Acacia auriculiformis A nilotica, Casuarina equisetifolia, Cordia rothii Emblica officinalis Morus alba, Pithecellobium dulce, Pongamia pinnata Tamarindus indica Tamarix sp Zizyphus mauritiana, Ailanthus excelsa, Albizzia amara, A lebbek Bauhinia variegata Hardwickia binata Moringa oleifera, Tecomelia undulata, Eucalyptus Sp Glyricida maculata Thesepesia populnea*
Shrubs	*Leucaena latisiliqua Sesbania grandiflora, S sesban, Glyricida maculata Desmanthes virgatus*
Grasses and Legumes	*Sehima nervosum, dichanthium annulatum, Cenchrus ciliaris Chrysopogon fulvus Panicum antidotale, Heteropogon contortus, Atylosia scaraboides Stylosanthes hamata S gracilis, Macroptelium atropurpureum, Desmodium sp*
(8) Humid and Semi-Arid Western Ghats	
Trees	*Acacia auriculiformis A melanoxylon, A nilotica Albizzia amara A procera Anogeissus latifolia Casia auriculata, Casuarinia equisetifolia Eucalyptus Sp Grevillea robusta Morus alba Peltophrum ptreocarpum, Pithecellobium dulce, Pongamia pinnata Zizyphus mauritiana Aegle marmelos, Ailanthus excelsa, Cordia dichotoma Hardwickia binata Moringa oleifera Tamarindus indica Glyricida maculata*
Shrubs	*Leucaena latisiliqua, Sesbania grandiflora, S sesban Desmanthes virgatus*
Grasses and Legumes	*Chrysopogon fulvus, Pennisetum clandistinum Ischaemum indicum Setaria anceps Panicum antidotale, Glycine javanica, Paspalum dilatatum, Stylosanthes hamata S gracilis Macroptelium atropurpureum*

After Patil and Pathak, 1977

Similarly, recommended trees and shrubs for silvipastoral systems based on edaphic conditions are given in Table 17.11.

Table 17.11 *Recommended trees and shrubs for silvipasture systems based on edaphic situations*

1	Hot arid	*Acacia nilotica* (Babool) *A tortilis* (Israeli babool) *Albizia amara* (Unjal) *Azadirachta indica* (Neem) *Dichrostachys cinera* (Vuruti) *Eucalyptus terminalia* *E camaldulensis* *Prosopis cinerea* (Khejri) *P juliflora*(Vilayati babool)
2	Semi arid, rocky and gravely	*Acacia catechu* (Khair) *Ailanthus excelsa* (Maharukh) *Albizia lebbek* (Siris) *Cassia siamea* *Dalbergia sissoo* (Shisham) *Dendracalamus strictus* (Male bamboo) *Hardwickia binata* (Anjan) *P juliflora* (Velayati babool)
3	Cold arid	*Juniperus communis* *J wallichiana* *Populus spp* (Pahari pipal) *Salix spp* (Bada)
4	Ravines	*Acacia nilotica* (Babool) *A catechu* (Khair) *A tortilis* (Israeli babool) *Albizia lebbek* (Anjan) *Dalbergia sissoo* (Shisham) *Dendrocalamus strictus* (Male bamboo) *Dichrostachys cinerea* (Vuruti) *Eucalyptus spp* *P juliflora* (Velayati babool)
5	Wetlends	*Baringtonia spp* *Eucalyptus robusta* *E rudis* *Casuarina equisitifolia* *Diosphyros embryopteris* *Pterospermum acerifolium* (Kanak champa) *Sapium sebiforum* (Vilayati shisham)
6	Riverbeds	*Acacia catechu* (Khair) *A nilotica* (Babool) *Dalbergia sissoo* (Shisham) *Psidium guajava* (Amrood) *Salix spp* (Bada) *Ziziphus spp* (Bair)
7	Cultivable Wastelands	*Acacia spp* *Albizia spp* *Hardwickia binata* (Anjan) *Leucaena leucocephala* (Subabool) *Sesbania spp*

Contd

Table 17.11 *Contd*

8	Saline areas	*Acacia nilotica* (Babool) *A tortilis* (Israeli babool) *Butea monosperma* (Palaash) *Dalbergia sissoo* (Shisha) *P juliflora* (Vilayati babool) *Salvadora spp* *Tamarindus indica* (Imli)
9	High altitudes in Himalayan region	*Acacia dealbata* (Acaci) *Aesculus indica* (Panger) *Cedrus deodara* (Deodar) *Eucalyptus viminalis* *Grevia oppositifolia* (Bhimal) *Juglans rigia* (Akhrot) *Morus serrata* (Kimu) *Pinus roxburghi* (Chir) *P Walli* (Kail) *Populus nigra* (Poplar) *P ciliata* (Poplar) *Plantamus orientailis* (Chinar) *Quercus floribunda* (Tilnji) *Robinia pendacacia* (Robinia)

Pastoral-silvicultural system

In this system, grasslands grow in forests and livestock are allowed to enter in the forest areas for pastoral purposes These are traditional systems varying in nature in different parts of India In this practice grazing is the major component with scattered trees This system is widely prevalent in semi-arid areas of Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Madhya Pradesh, etc The land is left fallow with the existing vegetation and protection by the community is provided A natural succession of grasses follow, which is protected for one to three years. In Rajasthan, religious-trust owned lands, called *'beed'*, are developed under pastoral-silvicultural system The villagers are permitted to graze on the pasture In Rayalaseema, livestock are allowed to graze and farmers are given right over fodder, fuelwood and other NTFP

In arid and semi-arid areas of Jhabua, this system is practised on 9000 ha under watershed development Commonly produced grasses are *Sukli, Bhatodi, Dinanath, Hamata*, etc Pastoral silviculture can be integrated in JFM under watershed area for improving productivity and sustainability

While some of the recommended grass-trees combinations for pastoral-silviculture in arid and semi-arid ecosystems are given in Table 17 12, some of the recommended grass-tree combinations for different rainfall areas are shown in Table 17 13

Silvo-agricultural systems (silviagricultural agro-forestry systems on arable land)

Trees valued for fuel, fodder, forage and fruits can be grown with crops in the field scattered in different locations or as intercrops or alley farming on field bunds *Alley farming* is defined as an agro-forestry system in which food crops are grown in alleys between rows of hedges The hedges follow the contour and can also be placed on conservation structures with trees and shrubs like leucaena or pigeon peas

Table 17.12 *Recommended grass-tree combinations for arid and semi-arid ecosystems*

	Grasses	Trees
	Semi-Arid Ecosystem	
1	*Sehima-Chrysopogon-Eremopogon-Heteropogon*	*Acacia,spp , Madhuca latifolia, Mazedarach, Anona squamosa, Azadirachta indica*
2	*Dicanthium-Bothriochloa*	*Acacia spp , Azadirachta indica, Hardwickia binata, Tectona grandis*
3	*Dicanthium-Cenchrus*	*Acacia spp*
	Arid Ecosystem	
	Grasses	Trees
1	*Lasiurus sindicus*	*Prosopis cineraria, P juliflora*
2	*Panicum antidotale Cenchrus ciliaris*	*Acacia senegal, Colligonum polygonoides, Ziziphus nummularia*

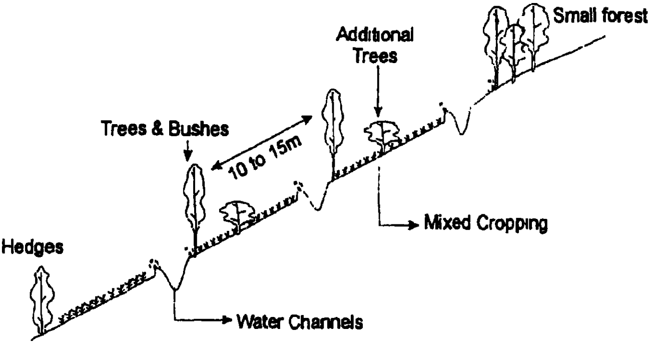
Table 17.13 *Recommended grass-tree combinations for different rainfall areas*

Rainfall(mm)	*Grass*	*Tree*
150-250	*Lasiurus sindicus*	*Prosopis juliflora, Colligonum polygonoides, Ziziphus nummularia, Salvadora oleoides, S persica*
250-400	*Cenchrus ciliaris,* *Panicum antidolate,* *Lasiurus sindicus*	*Acacia senegal, Prosopis juliflora, P cineraria, Calligonum polygonoides*
400	*C ciliaris, C setigens,* *P antidotale, D annulatum,* *Sehima nervosum*	*Prosopis cineraria, Acacia senegal, Acacia nilotica, Tecomella undulata, Ailanthus excelsa, Albizia lebbek, Dalbergia sissoo, Cassia auriculata*

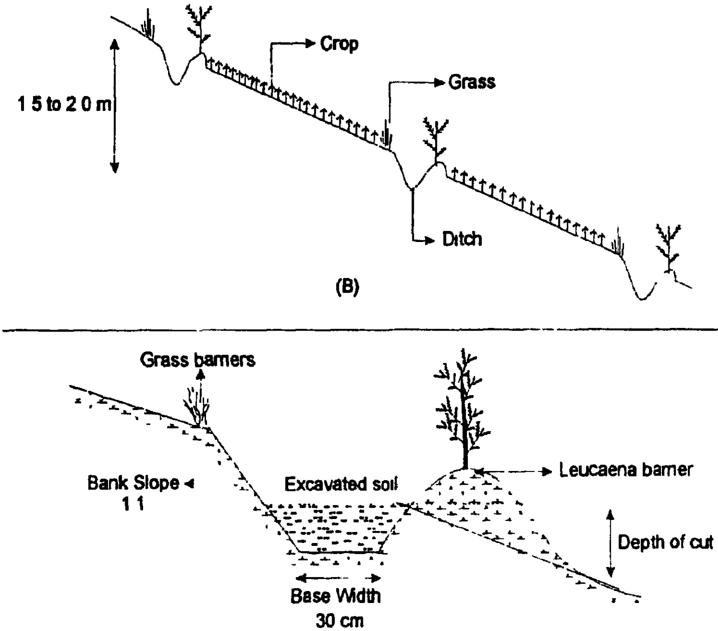
Trees and shrubs provide green manure and mulch to the soil which recycles soil nutrients. It suppresses weeds and creates favourable biological micro-climate for soil It reduces soil erosion and stabilises conservation structures on slopes Alley cropping is applied mostly in combination with physical measures on sloping degraded areas. Usually, cut-and-carry tree planting and vegetation are used with alley cropping Besides, bushes and shrubs (perennial fodder-species) can also be used In this system, trees are primarily important and crops are secondary. Planting must be narrow (say 1 m) in the hedge Timely weeding and pruning is needed Grazing should only be permitted between rows of trees, preferably with cattle tied Preference should be given to cut-and-carry operations followed by stall feeding Crop production is shifted between the rows of trees. Strips are left fallow after cultivation for five years It should be ascertained that grazing does not degrade the grass cover Crops are allowed only if soil fertility improves Crop rotation is recommended Regular cutting of tree branches for mulch and fodder and for decreasing shadow on crops is preferred (also see Figure 17.2).

Plantations on field boundaries is a common and acceptable practice. Fuel-fodder plantation, timber trees and grasses are also taken Field bunds or boundaries are used to grow fodder-fuel-timber without encroaching or affecting field crops *Eucalyptus* is taken

Figure 17.2 *Diagram of some agro-forestry systems*



(A) ' Eco - Farming in Rwanda (after Behmel and Neumann 1981)



(B)

(C) Agro - forestry system in Indonesia (after Benge 1980) on field boundaries for commercial use in Punjab, Haryana and Uttar Pradesh *Eucalyptus* are also raised in western Rajasthan as windbreaks and shelterbelts. Root effects of border rows of trees and hedges may be eliminated by digging a 0 5 m wide and 0.6 m deep trench at 1 m distance from the tree (Prajapati et al, 1971). Plantation crops under various shade trees are given in Table 17.14.

Table 17.14 *Plantation crops under shade trees*

Commercial crop	*Trees*
Tea	*Albizia spp, Acacia spp, Acacia lenticularis Derris robusta, Dalbergia assamica, Erythrina lithosperma, Grevillea robusta*
Coffee	*Alibizia spp, Erythrina lithosperma, Ficus glomerata*
Pepper	*Erythrina indica, Garuga pinnata, Gliricidia maculata, Grevillea robusta, Spondias mangifera*
Betel vine	*Sesbania spp*

Agricultural crops with commercial plantations

It is a widely practised system of agro-forestry in India Trees are usually planted in widely spaced rows and crops are cultivated in interspaces until the entire land is covered by the tree canopy Coconut (*Cocos nucifera*) is grown along with cocoa in certain areas of Kerala, Tamil Nadu, Karnataka and Andhra Pradesh. Both the crops are compatible Similarly, intercropping with Arecanut (*Areca catechu*) is also widely practised alongwith various crops It is important to thin and prune the tree branches periodically (see Table 17 15)

Table 17.15 *Recommended agricultural crops with commercial plantations*

Coconut	Cassava, paddy, grain legumes, Elephant footyam, Greater yam/lesser yam, Sweet potato/Chinese potato, Ginger, Turmeric, Banana
Arecanut	Paddy, Sorghum, Guinea grass, Turmeric, Ginger, Elephant foot yam, Banana, Cocoa, Black pepper, Pineapple, Betel vine, Cassava

Agricultural crops with horticulture plantations

Rainy season vegetables, winter vegetables, beans, *berseem*, etc , are generally grown with horticultural trees Some fruit plants like banana, papaya, strawberry, pineapple, etc , may be cultivated as field crops and they are grown as intercrops among trees. Citrus trees can be intercropped with winter vegetables, gram, *berseem*, etc , for 2-3 years Likewise, peach, plum and apricot can be intercropped with peas and beans for 2-3 years Intercropping of leguminous crops is profitable and remunerative with mango and litchi plantations Apple can be intercropped for 5-6 years with bean and peas. Saffron may be cultivated under almond plantations Certain recommended crops with fruit plantations are mentioned in Tables 17 16 and 17 17

Advantages and disadvantages of trees in agro-forestry

Trees grown and raised in agro-forestry has advantages and disadvantages Whether or not trees are an effective form of savings and security for the rural poor in watershed areas will vary according to social, economic and agronomic circumstances (Figure 17.3)

Table 17.16 *Recommended crops with fruit bearing tree plantations*

Trees	*Agricultural crops*
Mango	Rainy season vegetables,winter vegetables, grain legumes
Orange	Green manure crop (monsoon), vegetables and grain legumes (post-monsoon)
Apple	Grasses, grain legumes
Poplar	Soyabean, maize, grain legumes, potato, mustard, wheat

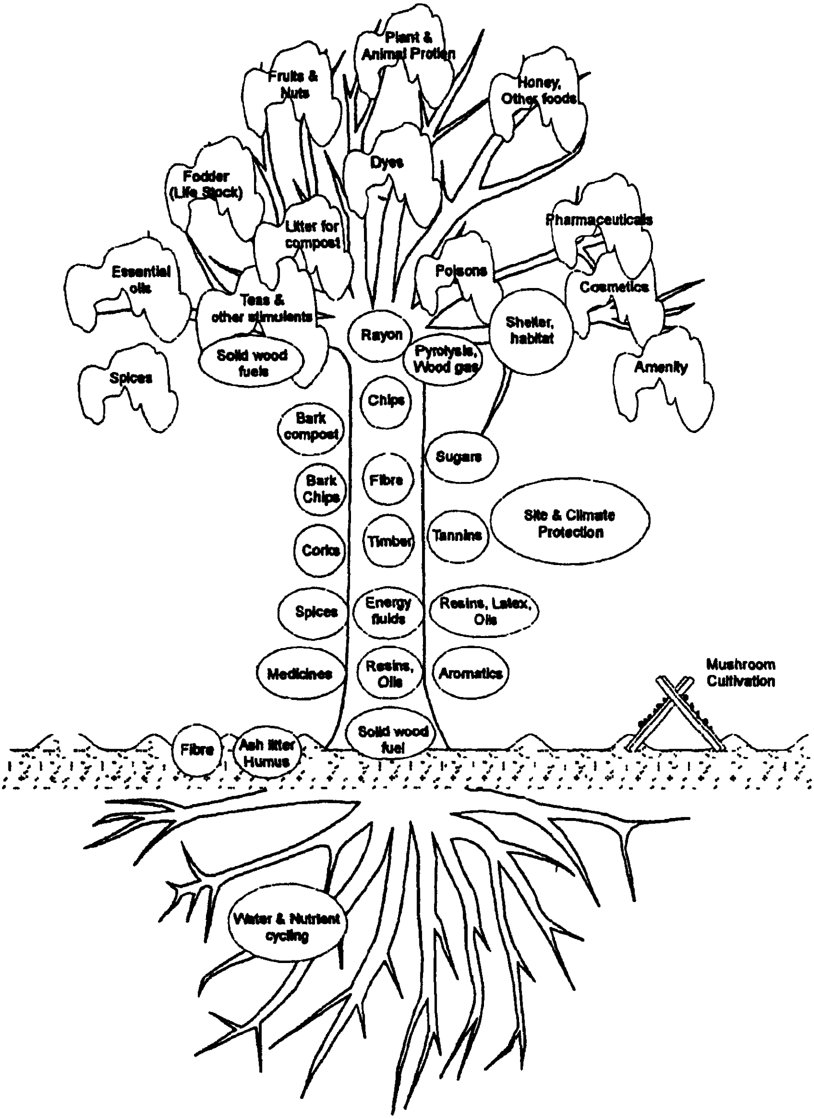
Table 17.17 *Spacing of fruit treees and recommended period for intercropping*

Fruit	*Spacing*	*Time for cropping to cover the space provided*	*Period available for intercropping*
Mango	10*10 m	7 Years	6 Years
Ber	6*6 m	4 Years	3 Years
Pomegranate	6*6 m	5 Years	4 Years
Date	8*8 m	8 Years	6 Years
Apple	6*6 m	6 Years	5 Years
Guava	6*6 m	6 Years	5 Years
Citrus	6*6 m	5 Years	4 Years
Stone fruits	6*6 m	4 Years	3 Years
Litchi	10*10 m	10 Years	8 Years
Sapota(Chiku)	10*10 m	10 Years	8 Years
Grape	3*3 m	3 Years	2 Years
Pineapple	0 9*0 9*0 25 m	9 Months	6 Months
Banana	1 8*1 8 m	6 Months	5 Months
Papaya	2 0*2 0 m	9 Months	5 Months

Advantages

Trees can have several advantages for poor people. They are cheap to establish, usually appreciate rapidly in value, are indivisible and manageable units and often regenerate after cutting. The rate of appreciation of trees may be faster. The sale of trees (or any other asset) is preferable to the mortgaging of assets in that it does not involve interest payments. Where trees can be coppiced, their sale has the advantage of no interest payments while avoiding the disadvantage of losing the asset, they will be recovered when the tree regenerates Trees can be mortgaged as well as sold Fruit bearing trees or trees which give recurring products give continuous source of income. During the initial years, trees can be considered as a form of forced saving, having little or no direct sale value With maturity, their rapid rise in value may provide a heightened incentive to poor families to save in order to gain more later After a few years, some trees have the advantage of being harvestable and saleable for timber or firewood at any time, and so provide a 'bank balance' that is easy to cash when needed, giving the grower greater flexibility than most other cash crops Due to their relative robustness to climatic extremes, trees make a valuable source of income at times of drought or flooding, when annual crops have failed

Figure 17.3 *Major tree products and functions*



Disadvantages

Beneficiaries adopting agro-forestry systems for the first time have higher risks due to failure to obtain seedlings in time, or unfamiliarity with silvicultural practices or with markets for tree products This is particularly so when trees are being grown primarily as a cash crop and where there is a significant opportunity cost, as when trees are grown on good agricultural land instead of cereals or pulses Cash crop (trees) may also involve increased dependence on alien institutions and middlemen (Saxena, 1990)

(a) *Insecure rights*: There may be disputes regarding rights over trees on the field boundaries,

(b) *Restrictive laws*· In India, most states have restrictive laws and regulations on rights over trees on private land especially on the cutting. Due to uncertainties farmers cut their trees and do not plant more Obtaining permits often involve long waiting, hassles, and bribes It increases the likelihood of exploitation by the middlemen (Chambers et al , 1989; Saxena, 1991)

(c) *Market risks (ignorance and exploitation)* Ignorance about the working of the market is sometimes another reason why prices are low as has been the case in Gujarat, Karnataka, Tamil Nadu and West Bengal (Shah, 1988, Saxena, 1991)

(d) *Market risks (demand for the product)* Farmers are more likely to be poorly informed about markets and prices for their products and hence more prone to financial losses In certain parts of India, tree planting has been intensive so much so that the pole market could not absorb the excess supply Prices fell and production became unprofitable (Saxena, 1990) Market forces fluctuate on uncertain basis Grazing by stray cattle in early stages and theft in later stages is a high risk in agro-forestry. Pest outbreaks may affect the survival and growth or productivity of tree crops

(e) *Long gestation period* Trees take several years to mature, which can be a disadvantage, especially if they are being grown as an alternative to seasonal crops, which provide a more immediate return

Designing agro-forestry for planners in watershed areas

Multifunctional nature of numerous agro-forestry technologies force the planners and implementors of watershed programme to diagnose various output sub-systems on prevailing land use patterns RRA and PRA techniques may assist in diagnosing and designing agro-forestry interventions. Productivity and sustainability should be main criteria for accepting a particular type of agro-forestry system It is essential to analyse and decide performance of output sub-systems in existing land use and appropriateness of suggested or recommended agro-forestry technology It can be arrived at by adopting following analytical activity sequence

(i) Characterise and identify essential features of structure and function in the existing land use systems and identify output sub-system

(ii) Evaluate the performance and identify the problems of sub-systems

(iii) Determine the constraints in effective performance of the sub-systems

(iv) Identify general potentials of interventions of an agro-forestry system

(v) Determine constraints in use of appropriate technology in agro-forestry systems.

(vi) Identify problems, strengths and weaknesses and potentials of recommended agro-forestry intervention

An *output sub-system* may be defined as the set of all activities, resources and other land use factors which are involved in the generation of an output intended to satisfy one of the basic production objectives of the household Sub-systems are important as they are most consistent with the way land users or beneficiaries manage their land, i.e., to produce desired outputs. A household is considered a functional equivalent in this regard because a household is normally the primary decision-making unit with respect of specific land use practices Methodology should include following output categories to be universally applicable and to adequately represent various idiosyncrasies of local land use system.

(i) *Food sub-system*· Seasonal shortage in food supplies, deficit and distress purchasing, drought-related crop failures at least once in five years, low milk and meat production
(ii) *Energy sub-system.* Insufficient fuelwood production, distress purchase of fuelwood, use of alternative energy systems.
(iii) *Shelter sub-system*: Lack of timber/poles suitable for construction, lack of fencing and shade trees, inappropriateness of shelter for livelihood, crop storage and livestock.
(iv) *Raw materials sub-system*
(v) *Cash sub-system.* Low net household income due to expenses on fodder, fuelwood, construction timber etc earning potential of livestock, cashflow in various seasons from output sub-system.
(vi) *Community integration*: Self-help groups and user groups in the community, frequency of the meetings, levels of mobilisation and self-reliance by the community

The first approach in identification of the problem is through intensive discussions with the beneficiaries Additional supplements like participant observation may help constructing the appropriate framework for designing. Spot diagnosis, casual network diagramming technique, quadrant matrix, transact, flow diagram, seasonal calendar, livelihood analysis, key probes, etc., may be effectively used to identify problems and constraints in land use

Specific problem solving agro-forestry alternatives may be instituted and recommended The recommended agro-forestry alternatives should address all the constraints of output sub-system A holistic and integrated approach or intervention may then be implemented with the help of MDT, WDC, SHGs and UGs

The planners and implementors should place priority on the technical aspects of agro-forestry, reclamation of wasteland by soil and water conservation measures, selection of appropriate crop, grass and tree species suited to edapho-climatic environment, market preferences and economic returns. A strong and sustainable institutional framework should be created and cultivated. A systematic and firm bond between the implementors and the community in watershed area would ease fears of exploitation, doubts about monetary benefits and misgivings about the superiority of new technology over long-tested traditional methods of raising crops The spread of agro-forestry systems in poverty-stricken, resource-poor wastelands in watershed areas may take time and energy Agro-forestry practices in private, common and government (revenue or forest) lands in a watershed area along with other approaches and measures form a strong base for effective watershed management

18

Horticulture Development

The term 'horticulture' is derived from two Latin words, 'hortus', meaning a garden, and 'cultura', meaning cultivation. Presently fruits, vegetables, flowers and ornamentals are grown in kitchen gardens and in large quantities on a commercial scale The present-day horticulture may be defined as the science and technology involved in the production, processing and merchandising of fruits, vegetables, flowers and ornamentals

It has been realised that farmers are not keen to plant trees for fodder and fuel, because of uneconomical prices, inadequate marketing facilities and the traditional practices of collecting these produce from community pastures and forests A suitable strategy to attract rural poor to participate in afforestation as a viable economic activity has to be evolved. Horticulture crops can be cultivated in degraded and denuded wastelands to assist control the soil erosion and conserve water and offer income opportunities in hostile areas and wastelands Poor quality land, falling under land capability classes V to VII, are considered for perennial vegetation like forests, grasses or horticultural crops It has been reported by various studies that fruit species can generate a higher income as compared to fuel species, fodder, etc Even on high gradient, denuded wastelands, raising of horticultural species is more profitable and economical per unit area per unit time Cultivation of fruit-bearing trees is very remunerative enterprise and a family can even thrive on 0 2 ha land Cultivation of fruits and nuts are more advantageous, as these tree species serve as a sustained source of regular income over very long periods, say 30-50 years, without felling trees Horticulture tree species, in addition, provide fuel, fodder, foliage and small timber as well Leaves from deciduous fruit trees, when used as mulch, provide protection to the topsoil from raindrop and runoff but also improve soil structure, reduce evaporation and increase infiltration The productivity and fertility of land is improved by formation of humus Tree-roots hold the soil particle, thereby reducing soil erosion to permissible limits (especially on erosion-prone areas) Such fruit bearing trees may be taken up on the crop land in a planned fashion

Crucial issues

Soil moisture conservation techniques

Under rainfed conditions, soil-moisture stress is maximum during summer and post-monsoon phase and is a major constraint for economic yields of most of the fruit crops. Such stress is more in degraded shallow lands, in semi-arid and sub-humid zones with poor water holding capacity of soil Various SWC techniques have been commonly adopted to fulfill considerable part of the moisture requirement A substantial part of post-monsoon rains could be effectively harvested from land surfaces (class VI to VII) through land shaping, use of polythene and mulching Specially in dryland horticulture, *in situ* moisture control is very important. Fruit bearing trees can be planted near the gully plugs in gullies or *nalla*-bunds in *nallas*, as more moisture is comparatively available as compared to the ridge or slope. By growing plants in a row at the bottom of slopes of V-shaped micro-catchments, it is possible to avoid supplementary irrigation for a considerable period in a young lemon-orchard (during January-April) (Ghosh, 1982) Sprinklers and drip irrigation have been found very useful for irrigating horticultural crops An indigenous technique is to put porous *matka* near the plant in the soil Water is changed every three days or so *Thalas* or micro-catchments of 2-3 m radius around individual tree could be constructed, so that more harvested water from runoff is available for the trees/plants

People's involvement

People's involvement is very essential in horticultural programmes The selection of species, planning and preparation of sites, execution and cultivation, planting and aftercare, protection and maintenance should be taken care of by the community at large and self-help groups in particular The identification of suitable species should be undertaken by the PIA involving the community. The preferential species should be agro-climatically suitable for the area as well Thus, a suitable balance between need and potential should be achieved If the plot happens to be a CPR, then its location and accessibility should also be decided by the community itself Proper protection and management systems should be evolved Horticulture development on personal plots should be taken only after assessing the motivational level of the owner and the logistical support possible Horticulture programme, involving community at all levels, ensures better survival of the plants, more remuneration from the enterprise and sustainability of the activity

Horticulture development opportunities

(a) *Agro-horticulture systems* Crops and fruit trees are grown together in numerous ways The companion crops are known as inter-cropping, under-planting, hedge-row planting or alley cropping

(b) *Homestead gardens* It is an age-old practice Rural communities depend upon tree-grooves in the backyard of the house or around the cluster of houses for supply of fruits, fodder, fuelwood, medicinal plants, etc. Such gardens provide supplemental nutrition and income to the household and relieve the pressure on natural resources The survival of the fruit bearing trees in homestead is higher (see Plate 47, Figure 18 1)

(c) *Community orchards* They may be raised on commons of the village or on

Figure 18.1 *A home garden on mixed land*

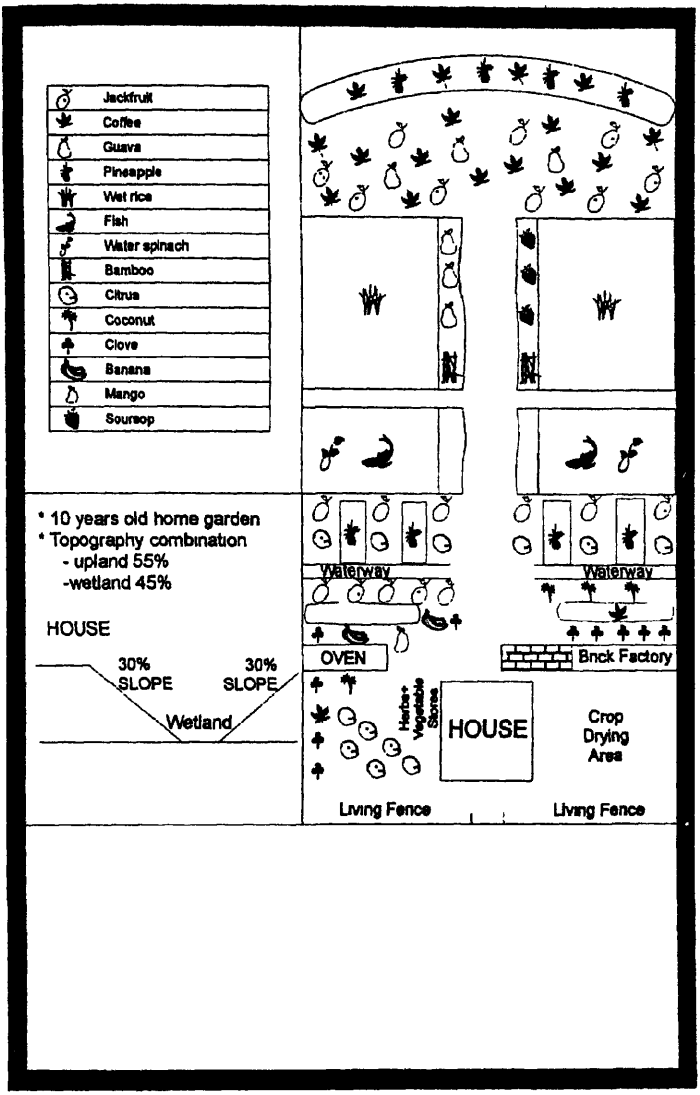


Plate 47 *To supplement nutritional requirement of the household, horticulture should be promoted in kitchen-gardens Women of the household could take care of these gardens*

government wastelands with the involvement of the community. Funds available under 'plantation' head in watershed development plan may be used for this purpose These orchards should be managed by local institutions or SHGs Equity in sharing of costs and benefits among the community members should be ascertained Effective management will help in maintaining sustainability.

(d) *Demonstration plots*: Farmers or villagers would not adopt fruit-bearing trees in their agricultural plots It needs lot of extension, persuasion and demonstration in the field The objective behind demonstrations should be to educate villagers about field preparation, manuring, spraying, mulching, pruning, irrigation, etc. Besides, concomitant awareness-building and capacity-building measures and processes should be initiated (Figure 18 2)

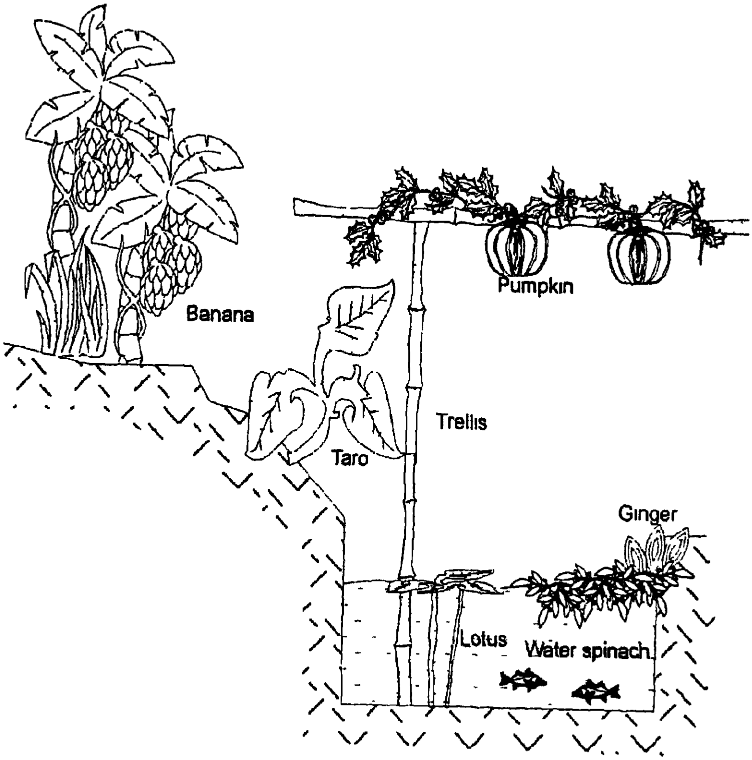
Fruit bearing plants

Fruits are produced on trees while small fruits grow on shrubs and vines The trees and shrubs may be deciduous or evergreen

Fruits-Trees *Deciduous*-Pome (apple, pear)
= Drupe (peach, cherry, plum, apricot)
Evergreen = Mango
= Citrus (orange, grapefruit, lemon, lime)
= Avocado
Small fruits = Strawberry, grape, gooseberry, currant, etc

Large-scale or commercial cultivation of fruit growing species should be undertaken after assessment of location and distance of market, soil condition, water availability,

Figure 18.2 *Fish pond and swamp land*



labour availability, natural flora, awareness about special techniques, etc. Most of the fruit trees are not very specific in soil requirement and can grow under varied and diverse soil and climate conditions. Similarly, there is an ability of a region to produce predominantly a fruit crop, depending upon climatic factors Thus, fruit crops can be classified geographically as follows:

Temperate fruits (1000-1500 m elevation) Peach, Japanese plum, Apricot, Almond, Vinifera grape etc) (above 1500 m elevation) Apple, Pear, Cherry, Walnut, etc

Sub-tropical fruits Orange, Grape, Lime, Lemon, Dates, Figs, Olives, etc

Tropical fruits Mango, Cashewnut, Banana, Pineapple, Papaya, Guava, Ber, Pomegranate, Custardapple, etc

Fundamentals of horticulture

(1) Selection of proper plant species by community should be ascertained based upon the needs and the potentials

(2) There should be an intermix of early fruiting and late fruiting trees. The economic re-

turns should be immediate as well as late.

(3) Precautious bearing of fruits should be discouraged.

(4) Ascertain supply of good quality seed and/or seedling before planting.

(5) In general, plants propagated by vegetative means retain the good qualities of their mother.

(6) The rainy season is the safest period of the year for planting operations. If irrigation facilities are available, the planting can be done at any time of the year

(7) As a thumb rule, shrubs should be planted 3-4 m apart, dwarf trees 4-6 m and tall trees 10-12 m apart.

(8) Planting may be done in various ways-square, rectangular, triangular, hexagonal, polygonal pattern

(9) In general, pits should be excavated upto a depth of 1-1 2 m and about 1 m diameter The pit should be refilled with the excavated earth along with leaf-mould, FYM, sand, etc The pits should be irrigated if possible before planting

(10) Pits may be dug up a month in advance Natural processes will ensure more survival

(11) Nurseries of the sapling should be located close to the plantation site. Transportation of the sapling should be carefully handled.

(12) Proper fencing of plantation site and protection of the planting should be ensured.

(13) Cash crops like papaya, vegetables, etc., may be cultivated in the open space between the trees during the first few years.

(14) Proper protection from insects, pests, fungi, etc , should be provided

(15) Fruit trees should have an adequate supply of water Presence of excess water and absence of sufficient water may harm the crop (Plate 48).

(16) Watering should be stopped at the onset of winter. Watering should commence when petals fall and fruits have started to set During watering, take caution that water does not come nearer than 50-90 cm of the collar of the plant

(17) Fruit trees should be pruned to secure good crop yield Pruning should be restricted to the removal of old dead branches or branches infested with pests and insects

(18) Root pruning of fruit trees should be done in two years Half of the operation in the first year and the second half later. Only the thin weak roots should be pruned leaving the main anchor roots intact.

(19) Fruits, in general, become soft and show colouration The naturally ripened fruits have better flavour and taste than the artificially ripened fruits.

(20) Fruits are often forced to ripen by being wrapped in straw, dampgrass, using ethylene, etc.

(21) Fruits should always be harvested with a portion of the stem

(22) Speedy transport of ripe fruits to the local market should be assured Different species have different shelf life

(23) Preservation of fruit, fruit processing, etc , should be taught to the farmers and villagers.

Fruit crops in wastelands

Achrus sapota (sapota or chiku)

It is cultivated in Gujarat, Maharashtra, Andhra Pradesh, Tamil Nadu, West Bengal, Bihar,

Plate 48 *In dry and hilly areas, earthen pot can be used as artificial micro-basin for fruit-bearing trees*

Uttar Pradesh, etc It is a slow-growing evergreen tree The main stem is strong and stout and gives out branches in a horizontal plane in systematic pattern The fruits are terminally single or in a bunch, depending on the variety The fruit is egg-shaped and round. The skin of the fruit is slightly rough resembling the potato skin in appearance Each fruit contains 4-5 black shining seeds. *Chiku* prefers moist tropical climate with high humidity, high rainfall and mild winters. It can be grown on a wide range of soils, but soils having very high percentage of calcium are not suitable

(a) *Uses* The fruits are edible The milky juice obtained from immature fruits is used in the manufacturing of chewing gum, statuettes, etc The tender leafy tips are edible The wood is used for agricultural implements, building construction, furniture, etc. The weak and thin branches are used as firewood Dry leaves can be used as mulching material during droughts

(b) *Propagation Sapota* is mainly propagated by vegetative methods such as air-layering, ground-layering or pot-layering and inarch grafting For inarch grafting the root-stocks of rayan (*Manilkara hexandra*) and mahua (*Madhuca longifolia, M latifolia*) are used The seedlings of *rayan* are raised by sowing the seeds in nursery in the beginning of monsoon Seedlings become ready in one year or so, for grafting purposes

(c) *Planting and care* The grafts are planted in pits dug well in advance during summer and filled with well rotten compost or FYM and soil in the ratio of 1 2. The distance of planting adopted is 8x8 m to 10x10 m The best time for planting is the beginning of the monsoon Just after planting, a basin is made around the plant. The plantation is cared for weeding and watering The plantation should be protected from browsing animals and pests. The fruits should be protected preferably by covering the tree with nets during the fruiting period. The trees start bearing fruit from the second or third year of planting, but economic yield is obtained from the seventh year onwards. The trees have a tendency to give increasing yield upto 30 years or so, under suitable growing conditions. The yield may vary from 400 to 1600 fruits per tree in the initial years. This number increases to 1500 to 2500 fruits per tree at the age of 30 years. Its important varieties are: *Kali Patti, Jhumukia* and *Mohangootee*

Angle marmelos/correa (bael)

It is often grown near God Shiva temples. It is a tall, deciduous and slow growing tree. Its leaves are trifoliate, branches have spines, and trunk is strong and stout. It flowers in May-June and fruits become ready after 8-10 months or by April-May. It requires sub-tropical climate. The *bael* tree is very hardy and can thrive well even in swampy, alkaline and stony soils having pH ranging from 5 to 10. However, well drained sandy loam soil is the best. The tree has the capacity to coppice and to produce root suckers.

(a) *Uses*: The fruit is most nutritive, it is rich in riboflavin The fresh ripe fruits are eaten. They have medicinal properties. From the pulp *sherbet* and syrup can be made The marmalade prepared from its fruits is often used to cure diarrhoea and dysentery. Fruits are also used in preparation of pickles. Gum obtained from the stem is similar to gum arabic The wood is used for making agricultural implements and the wood pulp is used as wrapping paper. The twigs may be used as firewood The leaves are used in worshipping Lord Shiva. The leaves are also used as fodder.

(b) *Propagation*: *Bael* is propagated by seeds, root suckers, budding and grafting For raising seedlings, the seeds are sown in nursery bed during April-May. The seeds germinate 3-4 weeks after sowing. The young seedlings should be protected from frost A higher percentage of success can also be obtained by patch and shield budding on young rootstocks of about 2-years old *bael* plants. The suitable period for budding is during May-July

(c) *Planting and care*: One or two years old seedlings are planted Planting can be done in February-March and June-July at a distance of 8x8 m to 12x12 m. Planting is done in pits 60x60x60 cm in size. About 5-10 kg or rotten FYM manure is mixed with soil in the ratio of 1:1 and filled in the pits well in advance. Fruit drop is a major problem. Seedling trees require 7-8 years to bear fruits, while plants start bearing fruits at the age of 4-5 years The fruit should be picked individually from the tree along with a portion of fruiting stalk and it should not be allowed to develop cracks on impact because of a very brittle peel During harvesting, to prevent fruits from falling on the ground, fruit picker should be used Well-grown trees of about 12-15 years old produce 300-400 fruits.

Anacardium occidentale (cashew or kaju)

Anacardium occidentale is grown in Andhra Pradesh, Maharashtra and Goa The cashew is a hardy and drought resistant evergreen tree and it is sensitive to frost It grows well in high rainfall areas of tropical regions, at an altitude of upto 100 m It grows best on sandy soils with a good drainage system. However, it can grow on stony soils on hill slopes It is less tolerant to saline soils

(a) *Uses*· The cashew-apple (thalamus) is juicy and edible The vine and other preservers are prepared from its pulp The sap from the bark provides an indelible ink. The seeds which are obtained by shelling the roasted fruits are a rich source of vitamin, mineral and have high calorific value The oil obtained from cashew nut seed is very expensive The shell oil is used in the manufacture of industrial flooring tiles, gums, inks, oil cloth, paints, water-proofing paper, acid and alkali resistant cements, etc. The wood is used for making agricultural implements Twigs may be used as firewood

(b) *Propagation* The cashew is grown mainly from seeds It can also be propagated vegetatively by air-layering, grafting or inarching, stone grafting or softwood cuttings.

(c) *Planting and care* The seeds can be sown *in-situ*, with three seeds per hill, later thinned into one healthy plant The distance for planting is 5x5 m or 6x6 m in poor soil and 7x7 m or 8x8 m in fertile soils For planting of grafted variety, pits of 60x60x60 cm are dug, and are filled with organic matter and soil in the ratio of 1 3 Planting is done during rainy season Weeding should be done at early stage of plant growth, i e , during the first year Water should be provided as and when needed Care is also taken against browsing animals Trees start bearing fruits after three years of planting However, economic yield is obtained after 10 years after planting and continues for about 20-25 years, after which the yield declines Flowering takes place during the dry season The fruits mature in 75-90 days These fruits are plucked and the nuts are removed from the apples They are dried in the sun for 1-3 days The seeds are eaten after roasting and cracking the nuts Oil-bath processes give quick uniform roasting and higher recovery of cashew-shell oil The average yield of cashew nut in India is 2 kg per tree and ranges from 2 kg to 30 kg per tree

Annona squamosa (custard apple)

Annona squamosa is a small to medium-sized fruit tree It is popularly known as *Sitaphal, Sharifa,* sugar apple and seep sop It is found growing in sub-tropical and tropical parts of India It grows well in semi-arid climate It can be grown on a wide range of soils The new leaves appear in spring followed by formation of flowers Ripe fruits are obtained in September-October Only about 2% of the flowers set and bear fruits.

(a) *Uses* The fruits are consumed when they are fully ripe. The pulp can also be mixed with milk icecream Oil is extracted from seeds and is used for making soap The cake may be used as manure. The wood is used for making ordinary agricultural implements Usually, the wood is resistant to damage from white ants, hence it is very useful for roof thatching The twigs may be used as firewood The leaves have medicinal properties

(b) *Propagation Annona squamosa* is mainly propagated on a commercial scale. Seedlings do not stand transplanting well It can also be propagated by vegetative methods, viz., budding, grafting and root-cutting Among vegetative methods, shield budding on its own rootstock is the best Budding with an year old budwood is usually performed during the period from February-June and in September For raising seedlings, the fresh seeds are sown in the nursery bed or in containers Prior to sowing in the nursery bed, the seeds are soaked in water for about 48-72 hours The seedlings grow slowly and hence care is taken regarding watering and weeding

(c) *Planting and care* Pits 45x45x45 cm in size are dug They are filled with topsoil in the ratio of 1 1. Planting is done at a distance of 4x4 m or 5x5 m An increase in this distance is not advisable The best time for planting is at the onset of the monsoon. Occasional irrigation is done in the first year of planting Weeding is necessary as and when they pose a problem to young plantation Pruning in *Sitaphal* is not advisable, as the fruit are borne on old wood as well as new wood. Very light pruning of over-crowded old branches may be occasionally performed. In late crop, during November-December, stone fruits are reported. The fruits are ready for harvesting in four months. They are harvested when they are firm and plump. The skin between the segments turns light yellow in colour when the fruits are fully mature A healthy tree of custard apple gives about 60 to 80 fruits.

Ananus cosmosus (pineapple)

Pineapple is grown mainly in Assam, West Bengal, Tripura, Uttar Pradesh, Andhra Pradesh, Kerala and Karnataka It is a humid tropical plant and grows well, both in the plains and also at elevations not exceeding 900 m. It tolerates neither very high temperature nor frost. It grows in almost any type of free-draining soil.

(a) *Propagation*: Pineapple is commonly propagated from suckers or slips Suckers arising from the underground parts of plant are commonly used. Slips arise from the fruiting stem and from the crown on top of the fruit. After the fruit is harvested stalks are cut into discs and used for propagation Plants grown from suckers produce fruits in about 18 months, whereas those from slips take over two years.

(b) *Planting and care*: Suckers or slips are first cured by stripping off the lower leaves, followed by drying in the sun or in partial shade for three to four days before planting They are planted either in flat beds, where there is no danger of water stagnation or in shallow trenches which are filled as the suckers grow and develop Care should be taken to see that the bud or 'heart' of the sucker does not get buried A planting density of 40,000 plants per ha can be followed, keeping a distance of 30 cm between plant and plant, 60 cm between rows and 90 cm between beds. The rainy season is the best time for planting The field is prepared by ploughing, before planting. In dry regions, the crop requires regular irrigation every week or ten days About 25 to 50 tons of farmyard manure per ha is applied in two doses in the sixth and twelfth month after planting. Only two suckers are retained on each plant After harvest, the plants are earthed up to simulate the rooting of the suckers. The plantation is allowed to remain on the same site for 4-5 years after which it is renewed Pineapple usually flowers from February to April and the fruits are ready from July to September. Sometimes, off-season flowers appear and they produce fruits in September to December The fruit is cut clean, retaining with it about 5 cm of the stalk

Artocarpus heterophyllus (jackfruit)

Artocarpus heterophyllus in an indigenous origin medium-sized evergreen tree It is grown in sub-tropical, moist tropical climate. It can be grown on a wide range of soils, but grows best in deep, rich and well-drained soil The crown is dense with dark green foliage The jackfruit tree has good coppicing ability It flowers from December to March and ripe fruits are available at the onset of monsoon The fruit size is the largest among the edible fruits They are borne on small leafless stalks arising from the trunk and main branches of the tree

(a) *Uses*: The ripe fruits are used as table fruit Immature fruits serve as a delicious vegetable Ripe fruits are fed to cattle Elephants eat bark, leaves and fruit The seeds are eaten either boiled or roasted The leaves are used as fodder The leaves are also used as dining plates (*dona*) by the poor The wood is used for making small furniture, agricultural implements and musical instruments The twigs are used as firewood The leaves, roots and flowers have medicinal value.

(b) *Propagation* Jackfruit is generally propagated by seeds and by vegetative methods (cutting, air layering, inarching, grafting, budding). The seeds can be sown directly in permanent sites. The seeds can also be sown in a nursery or in containers, preferably polythene bags, for raising seedlings. The time of sowing of the seeds is July-August The germination of seeds is rapid

(c) *Planting and care.* Nursery-grown seedlings cannot be easily transplanted because of long tap root, which breaks when the seedlings are uprooted However container-grown seedlings respond better to transplanting due to limited development of root system in a restricted area For preparing grafts, seedlings which serve as understock are grown only in pots For planting jackfruit, 100x100x100 cm pits are dug at a distance of 10x10 m or 12x12 m One year old seedlings or grafts are planted at the beginning of monsoon (June-July) When soil moisture is not a limitation factor, vegetable crops like brinjal, chilli, tomato, pulses, etc , can be conveniently grown as intercrops The jackfruit generally starts bearing fruit from the seventh to the eighth year after planting The flowers generally start appearing in December and continue upto March and the fruit ripens in summer Tender jackfruits that are harvested are used as vegetable Harvesting is done by cutting off the fruitstock carrying the fruits A tree bears about 300 or less fruits annually Individual jackfruit may weigh about 2-10 kg The distance of planting is about 5x5 m (high density)

Carica papaya (papaya)

It is commonly grown in Uttar Pradesh, Rajasthan, Punjab, Gujarat, Maharashtra, Bihar, etc It is short lived and fast growing softwooded small tree It is grown in tropical and sub-tropical climate It bears small, egg-shaped fruits Papaya requires well-drained, fertile, medium black and alluvial soils to give maximum yield

(a) *Uses* The ripe fruits are edible They are a rich source of mineral and vitamins The immature fruits are used as vegetable The ripe fruits are used for making soft drinks, jam, icecream flavouring, etc Latex is extracted from the immature fruit and dried. Papain is prepared from this, and is used in meat-tenderizing preparations, manufacture of chewing gum and in cosmetics Seeds have medicinal values

(a) *Propagation* Papaya is mainly propagated by seeds The seeds are sown on raised beds prior to beginning of heavy rains The seeds are sown at a distance of 5 cm in rows 10 cm apart The seedlings are ready for planting even 60 days after sowing but when they are planted at the age of 4-5 months, the plant grows better

(b) *Planting and care* The 60 days old seedlings can be transplanted, but the seedings of 4-5 months old are more suitable in terms of survival Pits are dug in the dimension of 30x30x30 cm to 45x45x45 cm and filled with 5 kg of well-rotten farmyard manure alongwith the soil It is advisable to plant two seedlings in one pit Planting can be done in February-March or at the beginning of monsoon The distance of planting depends upon the site of the plantation However, 2 4x2 4 m distance is recommended Papaya cannot grow successfully without application of irrigation at frequent intervals After about 5-6 months when flowers start emerging, the male plants should be uprooted (except 10-15%) The harvesting of the fruits is done when the first traces of yellow appear on the skin

Citrus reticulata (sweet oranges and mandarins)

The sweet orange (tight skinned orange) thrives better in a sub-tropical dry climate with low rainfall whereas the mandarin prefers more humid and tropical summers, warmer winters and higher rainfall Both these species can grow on a wide range of soil types.

(a) *Uses*· The fruits are edible. High quality juice and squashes are prepared from the fruits. The wood is used as firewood.

(b) *Propagation.* Propagation is by seeds and by budding. Two or three seedlings emerge from each seed. However, propagation by budding enhances early bearing. Seedling trees are slow in bearing fruits.

(c) *Planting and care*: For planting, pits of 70x70x70 cm are dug and filled with topsoil mixed with about 20-25 kg FYM, 900 gm of bonemeal and 3 kg of wood-ash. The distance of planting is 5x5 m or 6x6 m The time of planting is pre-monsoon or post-monsoon season. Young trees have to be watered regularly throughout the year during the dry season. Each tree bears around 100-200 fruits

Citrus limon (lemon)

The lemon (*Citrus limon*) fruits are oval or elliptical with a pointed nipple. Fruit surface is smooth, light yellow and the core is solid A loamy soil of uniform texture upto a depth of 2-3 m, having good fertility is ideal.

(a) *Uses*· Both the lime and lemon are used for the preparation of refreshing soft drinks, in seasoning food, in the making of pickles, in preparing commercial citric acid and citrate of lime and in making cosmetics. The wood is used for firewood

(b) *Propagation* The *Kagzi* lime and lemon are propagated by seeds, layering and budding About 3 or 4 seedlings emerge in each seed. *Kagzi* lime is propagated by seeds in most places The seedling trees can withstand the harsh climate better than the budded plants.

(c) *Planting and care* The planting is done at a distance of 5x5 m or 6x6 m The young plants should be protected from intense heat during summers and from frost injury during winters. About 50 kg FYM, 500 gm N, 400 gm P_2O_5 and 1000 gm K_2O (fifth year and onwards, every year) is recommended. Application is done in December-January before spring flowering, and the second application is done in June-July Lemon trees begin to bear crops from the fourth year onwards after planting The fruits mature in six months after flowering. In north India, the main harvesting season is in the months of August-September Fruits are ready for picking when the colour changes from green to yellow The fruits are usually harvested by means of a pole-harvester with an iron hook fixed at the end The fruits fallen on the ground are collected The yield varies from 100-150 q/ha

Emblica officinalis (aonla)

Emblica officinalis (aonla) is indigenous to Indian sub-continent It is a medium to tall tree with feathery leaves and a well spread out crown The colour of the bark is grey and it is smooth The fruits ripen from November to February *Aonla* can be grown in moist as well as dry sub-tropical and tropical climates *Aonla* can tolerate slightly alkaline soil However, well-drained fertile soils are the best The tree is sensitive to frost as well as drought It has the capacity for coppicing and pollarding It can also produce root suckers

(a) *Uses* *Aonla* fruits are edible They are the richest source of Vitamin C out of all other frutis Various products like candy, dried chips, tablets, jellies, pickles, powder, *murabba*, *chutney*, etc , can be prepared The fruits are also used in preparation of hair-oils. The seeds and roots are used in medicines The bark, leaves and fruits are used for tanning *aonla* is very important component in Ayurvedic preparations like *Triphala* and *Chavanprash*. The wood can be used for making furniture and agricultural implements The twigs are also used for firewood and for making charcoal Fuelwood has a high calorific value. The leaves are also used as fodder The branches (smaller ones) are cut and used as green manure.

(b) *Propagation* *Aonla* is propagated by seeds and by vegetative means (inarching and budding). The seedling trees produce small-sized fruits of inferior quality, whereas trees raised through vegetative means give fruits of high quality For raising seedlings, seeds are sown in nursery bed or in polythene bags. Sowing is done in the month of March-April with fresh seeds Prior to sowing, seeds may be soaked in 500 ppm GA3 for 24 hours to give higher percentage of germination (90%) Regular watering is necessary for early germination and growth of seedlings Seedlings attain plantable size or can be used in the form of rootstock in one year Shield budding is the commercial method of propagation The most important factor is the proper selection of mother plant which is highly fruitful and the buds should be taken from a branch which has a good number of female flowers.

(c) *Planting and care* For planting, the pits of 50x50x50 cm should be dug and filled with soil and 10-15 kg of FYM Planting is done in July-August at a spacing of 8x8 m or 9x9 m in fertile soil, whereas in poor and marginal soils it is done at a distance of 4x4 m to 5.5 m Young plants should be provided irrigation during summers *Aonla* plants start bearing after 6 years Flowering occurs in spring and the fruits mature during winters About 200-300 fruits are usually available per tree per year.

Its important varieties are Banarasi, Chakaiya, Hathijhool, Krishna, Kanchan, etc.

Mangifera indica (mango)

Mangifera indica (mango) is native to India Mango grows widely in tropical and subtropical climate. Mango is widely grown in Uttar Pradesh, Bihar, Madhya Pradesh and Andhra Pradesh. Dry weather flowering and fruiting is suitable Mango trees are damaged by frost. Mango can be grown on a wide range of soil types However, soils with poor drainage and strong acidic and alkaline properties are not good

(a) *Uses* Mango trees provide fruits of excellent quality, a rich source of Vitamin A and C The ripe fruits are used in the preparation of juice, squashes, jams, jellies, preserves and so on The immature fruits are used in pickles, *chutneys*, *amchur* and culinary preparations The leaves are also fed to cattle as emergency feed The wood is used for furniture, agricultural implements, building construction, plywood, packing cases, etc. Thin twigs are used as firewood Thin twigs and leaves are also used in *hawans* According to Hindu mythology mango is accepted as a holy tree Festoons of mango leaves are used as decoration at Hindu ceremonials and festivals

(b) *Propagation* Mango is propagated by seeds and by vegetative means. The trees raised by seedlings are large and bear late Quality and yield of fruits are different with varying seedlings It is advisable to adopt vegetative methods, viz , inarching, stone and softwood grafting, etc., for its propagation Seedlings can be grown in nursery beds or in polythene bags.

(c) *Planting and care*: About one year old seedling or graft is suitable for planting. Prior to planting, pits 60x60x60 cm to 100x100x100 cm are dug Pit size is kept comparatively large when the soil is poor. The distance for planting is 8-10 m in dry areas and 10-12 m in humid areas where vegetative growth is luxuriant. Under high density planting mango can be planted at 5x5 m distance As regards filling of pits, they are filled properly with a mixture of 5-10 kg of well rotten farmyard manure (generally the ratio of FYM and soil is kept at 1·1 or 1·3). This operation should be completed before planting. The best time for mango planting is during monsoon. Mango plants require proper watering for about three years. The mango plants start bearing at the age of three years but should not be allowed to produce fruits. Thereafter, plants are allowed to bear fruits from fifth year.

Its important varieties include Alphonso, Langra, Dasheri, Safeda Lucknow, Chousa, Bambai, Noorjahan, Muradabadi, Nagulapalli, Neelum, Totapuri, Mallika, etc

Morus alba (mulberry)

Morus alba (mulberry) is a medium-sized tree with spreading crown It is a fast growing tree It is widely cultivated in western Himalayas upto an altitude of 1200 m, Jammu & Kashmir, Punjab, Haryana, Uttar Pradesh and Madhya Pradesh. It can be grown on a variety of soils but alluvial, deep, loamy soils are better for its growth It does not grow well in alkaline soils The trees withstand drought and cold but cannot withstand water logging conditions. Mulberry is a short-lived tree

(a) *Uses* The leaves are used for rearing silkworms and are good fodder. The fruits are sweet, succulent and edible. The wood is used for making boats, furniture, hockey sticks, etc. The twigs are used as fuelwood. The young branches can also be used for making baskets.

(b) *Propagation*. Mulberry is propagated by seeds and stem cuttings. Propagation by budding, grafting or layering is also successful For raising seedlings, the seeds are sown in May-June. They are sown in finely prepared nursery beds at a distance of 25-25 cm. The seeds are small, therefore it is necessary to mix them with ash or sawdust at the time of sowing to ensure uniform seed sowing Germination of seeds is completed in 12-15 days after sowing.

(c) *Planting and care*. Planting is done when seedlings are about one-year old. The stumps can also be prepared and planted Always, planting of seedlings should be done along with the entire ball of earth It is advantageous to clip-off some leaves including upper portion of the seedlings at the time of planting The size of pits is about 30x30x30 cm to 45x45x45 cm About 10-15 kg FYM is mixed with surface soil and the pit is filled till the top Close planting (3x3 m) is needed for sericulture For fruit production it is planted at a distance of 6x6 m. *Morus alba* can also be propagated successfully by stem cuttings Hardwood cuttings of 20-25 cm length may be planted in nursery beds in the month of December-January The plants become available for planting in the months of July-August Water requirement of mulberry is high and the tree may suffer from drought conditions The seedlings/saplings and trees are susceptible to fire Mulberry flowers in February-March and the fruits mature by May-June About 10-12 kg of fruits are harvested per year from a fully developed tree The fruits are highly perishable and are unfit for storage

Musa paradisica (banana)

Banana (*Musa paradisica L*) occupies over 1,64,000 ha, mainly in Tamil Nadu, West Bengal, Karala, Maharashtra, Gujarat, Karnataka, Assam, Andhra Pradesh and Bihar Its commercial importance is mainly limited to the more tropical conditions, such as those prevailing in central, southern and north-eastern India It is a moisture and heat-loving plant and cannot tolerate frost or arid conditions.

(a) *Propagation.* Propagation is by suckers or off-shoots which spring at the base of a banana-tree from underground rhizomes Vigorous suckers, with stout base, tapering towards the top and possessing narrow leaves are selected for planting. Each sucker should have a piece of underground stem with a few roots attached to it

(b) *Planting and care* Banana suckers can be planted during the rainy season. They are planted in small pits, each just enough to accommodate the base of a sucker The planting-distance varies from 2x2 m in the case of dwarf varieties to 4x4 m in the case of very tall varieties. An application of 20-25 kg of farmyard manure, together with about 5 kg of wood-ashes per plant is given at planting time The removal of suckers, dry leaves and pseudostems, from which the fruits have been harvested, constitute the main after-care. Daughter-suckers should be removed promptly until the mother-plant flowers, one daughter-sucker may be allowed to take its place The removal of dry leaves and useless pseudostems requires to be done in time After all the fruits are formed, the pendant portion of the remaining inflorescence along with the heart should be removed The propping of plants with bamboo poles, especially those which have thrown out bunches, is necessary wherever damage by wind is apprehended Where the wind damage is recurring, dwarf varieties should be preferred Banana plants require very heavy irrigation Irrigation is given in seven to ten days. Stagnation of water in the soil is not very congenial to the proper growth of banana and, hence, the drainage of soil is also essential Early varieties commence flowering in about seven months after planting and the fruits take about three months more to ripen. The bunch is harvested just before it attains the ripening stage When the fruits have reached the full size, they become plump, and mature with a distinct change in colour. For long transport, the bunch may be harvested somewhat earlier The yield varies considerably from 25,000 to 55,000 kg per ha The ripening of banana is done in several ways, e g, exposing the bunches to the sun, placing them over a hearth, wrapping them up in green leaves and piling them in a heap, storing them in closed godowns or smoking them in various ways One of the common ways is to heap the fruits in a room and cover them with leaves, after which fire is lit in a corner and the room is made air-tight Ripening takes place usually in 30-48 hours The application of vaseline, a layer of clay or coal-tar to the cut ends of the stalks prevent rotting during ripening and storage

The important varieties are Poovan, Champa, Amrit sagar, Basai, Rajeli, Rastoli, Maurithus, Robusta, Virapakshi and Morthan

Psidium guajava (guava/amrood)

Psidium guajava (guava/*amrood*) is a hardy and long-lived tree It grows upto a height of in cotton and jute industries. The bark and leaves are used for tanning. The wood is used for tools, furnitures, fuel and makes excellent charcoal. It is used in gun powder and by goldsmiths. The wood is also useful for firing brick kilns.

(b) *Propagation*: *Tamarind* is propagated mainly by seeds, and also by root suckers on a small scale. The ripe fruits are collected in March-April and seeds are extracted and are sown in the nursery beds 20-30 cm apart both ways. Germination of seeds take about 20-30 days Seedlings grow very fast. Seedlings become ready for planting in July-August. Planting is done in 30x30x30 cm pits At the time of planting tap root is trimmed. The stumps prepared from 12-15 months old seedlings can also be planted at the beginning of monsoon. Planting distance in the beginning should be 5x5 m which becomes 10x10 m or 15 x15 m after thinning twice or thrice.

Zizyphus mauritiana (ber)

Zizyphus mauritiana (ber) is a small, spiny, bushy tree with a wide spread crown. It prefers to grow in hot and dry tropical and sub-tropical climate It develops deep tap root It can tolerate waterlogging conditions for a short duration. It is comparatively frost hardy *Ber* is one of the most salt tolerant species.

(a) *Uses* The fruits are nutritive (contain vitamins A, B and C and minerals) and can be eaten fresh, dried or pickled The leaves are used as fodder The wood is used for making agricultural implements, tool handles, tent pegs, toys, golf clubs, etc The wood is very suitable for making high quality charcoal. The twigs are used as firewood The bark is used for tanning. The tree can serve as a host for *lac* insect The leaves can also be used to

Plate 49 *Improvement of native horticultural varieties by bunding and grafting results into increased production of pest resistant, better quality fruits Such operations can be carried out by the previously trained village volunteers*

feed *tassar* silk-worms

(b) *Propagation. Ber* is propagated by seeds and by budding. For raising seedlings, the seeds are sown either in nursery beds or in containers. Germination may be enhanced by breaking the hard shell carefully, after which it take only about 7-10 days Seedlings are slow growing. The seedlings should not be allowed to stay in nursery beds for long period Container grown seedlings are better *Ber* is propagated commercially by budding. The main budding techniques which have been reported to give higher success are shield, patch and flute budding The best time for budding operation is before the onset of monsoon preferably the month of June (Plate 49, also see Figure 18 3 a, b)

(c) *Planting and care.* The seedlings or transplants are planted out in July-August in 30x30x30 cm to 45x45x45 cm pits Planting is done at (6x6 m), when the aim is fruit production Bearing of fruits start after three years Fruit yields can be increased by application of manures, irrigation and pruning. Farmyard manure at the rate of 10-15 kg per tree may be applied in June-July Water requirement is more during the fruiting stage Pruning is desirable to build-up a strong framework of the tree and to induce young shoots which bear flowers and fruits. It is done in the month of April-May Harvesting is done when fruits are fully ripe, fruits are graded according to size Average yield of *ber* is 30-50 kg, which is supposed to be good yield on marginal lands However, improved varieties, when grown on fertile soil and given irrigation, yield 80-200 kg of fruits per well-grown tree

Important varieties of *ber* are Kaithali, Umran, Mehroon, Banarsi Karka, Seo, Dandan, etc

Vegetable cultivation

Vegetables constitute an important item of diet Most of the vegetables are short duration crops and can easily be produced in quick succession on the same plot. The daily minimum requirement of vegetables is 250 gm per head, i e., about 20% of the daily requirement of the total food of an adult. In order to improve the quality of the diet of the people, it is essential that the production of vegetables should be considerably increased. The present area under vegetable cultivation can be increased or the yield per unit area can be increased by adopting better agricultural techniques (see Plate 50 a, b).

Seed is an important factor governing the production and productivity of vegetables. An adequate supply of good quality seed has paramount importance in promotion of vegetable cultivation in watershed areas. Vegetables can be grown in either of the six different types of vegetable gardens· (a) home gardens or kitchen gardens, (b) market gardens, (c) truck gardens, (d) gardens for processing, (e) gardens for vegetable-forcing, and (f) gardens for seed production There are dozens of vegetables, which can be classified on the basis of essential methods of culture

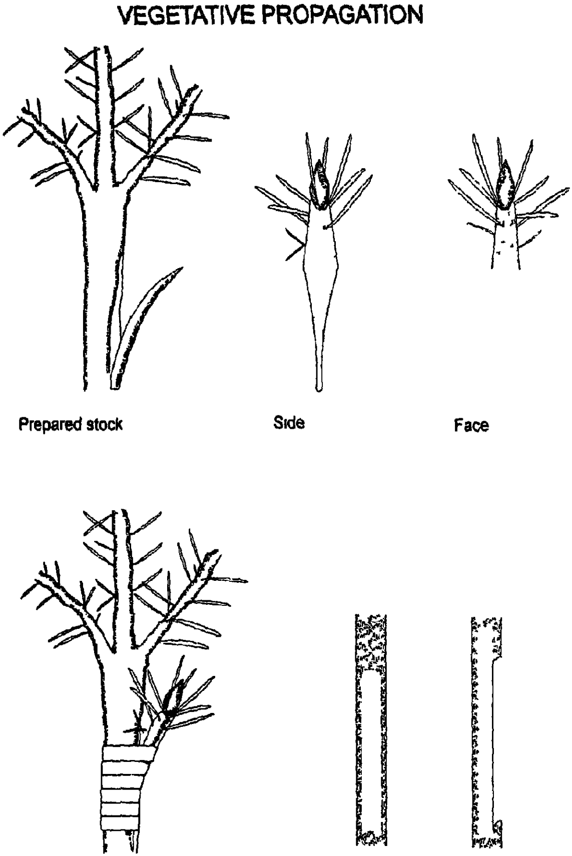
(1) *Solanaceaus fruits*· Tomato, brinjal, chilli (sowing in June-July for the autumn crop and November for spring-summer crop)

(2) *Cole crops* Cabbage, cauliflower, Chinese cabbage (sowing in May-August for cauliflower and in September-October for other crops).

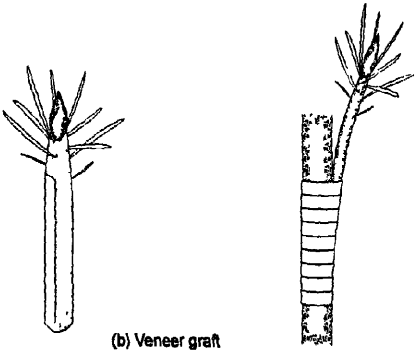
(3) *Root crops* Radish, Turnip, Carrot, Beet (sowing in September-October in temperate areas, and August-October in tropical climate)

(4) *Bulb crop* Onion, garlic, leek, welsh onion (sowing in October-November for onion,

Figure 18.3 (a, b) *Steps in making side and veneer grafts*



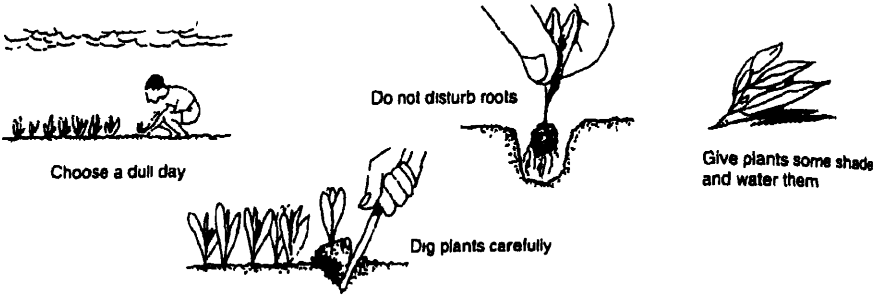
(a) Side Graft



(b) Veneer graft

Plate 50 (a, b) *Vegetable cultivation is an easy way for income generation for women groups*

Figure 18.4 *Transplanting vegetable seedings*



and September-November for garlic).

(5) *Peas and beans (legumes).* French bean, cowpea, cluster bean, sem (sowing in August-September for French bean, in February-March and June-July for cowpea and cluster bean, in June-July for sem).

(6) *Cucurbits.* Cucumber, Musk-melon, water-melon, pumpkin, tinda, etc. (cucumber and pumpkin can be grown in summer and rainy season, and musk-melon, water-melon and tinda can be grown in summer)

(7) *Sweet potato·* Sweet potato (in northern India, the cuttings are planted during June-July and in central and southern India during October-November).

(8) *Bhindi·* Bhindi (sowing in early strip for summer crop and in June-July for the rainy season crop).

(9) *Salad crop*: Lettuce, celery, parsley (sowing in August-October)

(10) *Leafy vegetables, potherbs or greens. Palak,* spinach, mustard, etc. (sowing in September-November).

(11) *Other root crops* Colocasia, yam, tapioca (sowing in June-July).

(12) *Perennial vegetables*: Asparagus, rhubarb, globe artichoke (sowing in September-October).

Vegetable cultivation is an advanced stage of cultivation and requires agricultural expertise Farmers should have easy accessibility to HYV seeds, organic/inorganic fertilisers, pesticides, etc. Perennial availability of water for irrigation is essential. Cultivation on commercial basis should be undertaken depending upon the proximity of the market.

Floriculture

Floriculture may be taken up as an alternate source of income. Flowers are important economically as they are required in festive occasions, religious ceremonies and social functions. Extraction of perfumes require wide variety of flowers Perfumes are used in manufacturing soaps, cosmetics, hair-oil and in food. Besides, the seed and nursery business may become a source of income and may provide employment for many. Rose, Jasmine, Chrysanthemum, Orchids, Gladilus, Bougainvillea, Tuberose, Marigold, etc, may be cultivated, if logistics favour, in watershed areas as commercial activity.

19

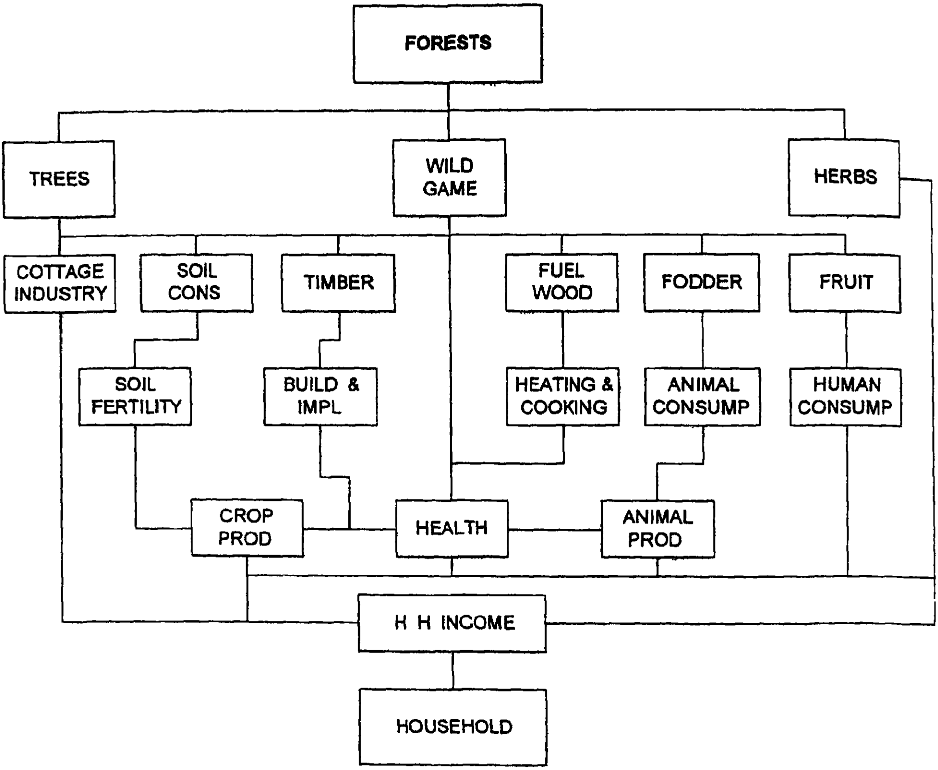
Joint Forestry Management in Watershed

There has been a major policy shift in the forestry sector towards a decentralised and people-oriented forestry This trend is reflected in major policy reshuffle which has taken place in many states of India Thrust to develop alliances with local community to regenerate degraded forests within the watershed area has been the major paradigm in Jhabua model of watershed development The local community gets increased access and usufruct rights over the degraded forests in return for increased responsibility for protection and management of the wasteland patch (see Figure 19 1)

So called 'planned and scientific' forest management has alienated the local community groups from the different natural resources on which they have depended for generations. Increasing biotic pressure, encroachments, development of forest-based industries, scarcity of agricultural and residential lands, transfer of land for development activities and uncontrolled grazing has grossly depleted the natural resources This has been compounded by the community loosing much of their control over natural resources through nationalisation of forests, transfer of tribal lands to non-tribals and the implementation of large 'development' projects in forest areas All these trends have increased poverty and deprivation of forest dependent poor households Forest department was trying to play the role of protector, which gradually changed to conservator Timber-oriented management was predominant and objects of management were the hands of forest department

Participatory forest management (PFM) became the philosophy with the advent of new Indian Forest Policy in 1988 It emphasises the goals of managing natural resources as the means towards achieving the ultimate objective of improving the lives of dwellers PFM in watershed areas is implemented to regenerate degraded forests and to alleviate rural poverty by associating members of watershed association in the protection, conservation and management of community/government degraded forest in lieu of usufruct rights of fuelwood, fodder, timber and non-timber forest produce (NTFP) It envisages active association of rural communities in planning, management and rejuvenation of degraded forests in their proximity Due to the Government of India guidelines issued in 1990 to all

Figure 19.1 *Linkages between forests and households*



states, 15 states have adopted the joint forest management (JFM) strategy. According to J.Y. Compbell, JFM is an attempt towards decentralisation and empowerment of local communities for the management of natural resources (see Plates 51, 52 and 53).

JFM seeks to foster partnership between state forest departments and local institutions of forest users and right holders on the basis of sharing benefits and forest management responsibilities JFM represents an evolutionary process of transformation of a state controlled resource to a common property resource in which the state is only one of the partners. JFM reflects a shift to a negotiated set of uses and management rules in which the local community is a recognised partner Philosophy of JFM is based on several key assumptions:

— degraded forests can be regenerated with the help of local communities.
— local communities will participate only if they have an incentive to do so.
— giving communities a share in timber harvests is a sufficient incentive (Saigal, 1996)

Local initiatives for regeneration and protection

In most of Indian states, there has always been a grass root forest protection movement. It is estimated that thousands of village groups are regenerating an estimated 4 lakh ha of forests in the eastern states of Orissa and Bihar, and on a smaller scale in Gujarat, Rajasthan, Karnataka, Andhra Pradesh and Madhya Pradesh (Sarin, 1995). These group have been involved in protecting forest patches adjoining their villages in response to the forest degradation and the resultant hardships Such informal groups, managing forest resources without outside help (governmental or non-governmental), were strong in areas where

Plate 51, 52, 53 *Protection and conservation strategies adopted and promoted through organised informal groups, village forest committees/forest protection committees on CPRs and adjoining forest areas are an integral part of watershed management programme*

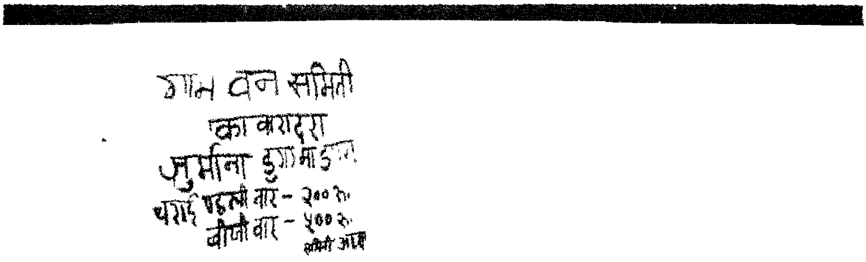


Plate 51, 52, 53 *Contd*

community heavily depended on forest for livelihood and where community-based resource management was prevalent

Most of such groups are hamlet (*para/falia/tola*)-based as the community in a hamlet is more homogeneous. Such activities were in practice for centuries in numerous hamlets in Jhabua district. These groups had their own costs and benefits sharing among all the members. People had been contributing grains or cash to employ a local guard to control access to the forest resources. Such groups reap benefits among themselves unless forest department intervenes and creates obstacles. Such groups (estimated at about 240) in Jhabua, have been used in protection of degraded forests and wastelands under watershed. In doing so, respect towards their wisdom, customs and processes was duly paid But, certain problems cropped up, such as·

(1) Long-term common property resource management could not be ascertained.
(2) Equity (gender or class) sharing of usufructs or benefits were not existing
(3) Legal rights over the resources regenerated by such groups did not belong to them. Outsiders (other passer-by or forest department) could interfere in their management.
(4) Responsibility was not properly distributed
(5) Certain beneficiaries living on the fringes of the degraded forest were not included in the group.
(6) Unscientific methods of procedures were used, which harmed flora and fauna (see Chart 19 1)

Chart 19.1 *Procedure for systematic JFM intervention in watershed*

Phase-I Identification of appropriate patch of degraded forest

- Priority is given to hamlets where traditionally and customarily informal groups are engaged in forest management
- Priority is given to hamlets/villages where the community is more or less homogeneous
- Degraded forest patch should be on community land (belonging to revenue or forest or panchayats)
- Patches close to the habitation of the community should be preferred
- Certain patches should be left unprotected to ease out immediate community needs for cattle grazing, fodder, firewood or *nistar*.

Phase-II Initial discussions

- Discussions in different SHGs and UGs regarding the importance of forest protection committee (FPC)
- Identification of strengths, weaknesses, opportunities and threats of the community using PRA and RRA techniques
- Collection of baseline data regarding demographic, climatic, geographic, economic condition/situation
- Initiation of group dynamics and finalisation of group objectives, goals, processes etc
- Initiation of the community in the formation of FPC under JFM

Atleast following informations should be gathered

- socio-economic condition of the community,
- status of the agriculture and potentials to improve it,
- resource mapping and soil and water conservation measures,
- availability of MFP, their need and utilisation,
- wastelands of the village, their present use and encroachments,
- fodder-fuelwood demand and potential,
- number of cattle, present grazing practices and facilities and measures to decrease/abolish uncontrolled grazing in degraded and protect areas, and

Contd

Chart 19.1 *Contd* .

- analysis of scope for village-based industries and their forward and backward linkages.

Phase-III Second round of discussions

- Based on initial discussions and suggestions by the community, procedure should be laid down regarding nomination of members, organisation of the executive body and ex-officio secretary, registration, etc.

Phase-IV Formation of FPC/VFC·

- Atleast 50% beneficiaries should be present, one adult member from every household of the village should be present
- Sarpanch of the concerned panchayat should be present Divisional Forest Officer (DFO) or authorised person not below the rank of forester should preside over such meeting
- The decision to set up FPC/VFC should be taken unanimously
- It should be approved and registered by DFO(T)

Phase-V· Formation of executive body

- FPC/VFC should discuss in the same meeting regarding formation of executive body
- One member from every ten household should be nominated, 50% of the members should be women.
- All the members of panchayat should be nominated as members.
- Forestguard, *kotwar,* teacher and sarpanch of panchayat should be ex-officio members Forestguard would be ex-officio secretary of the executive body
- Members of the executive body should elect a president among themselves
- Executive body should meet at least once in a month.
- It should be approved by DFO(T)

Phase-VI· Plan preparation

- Four year micro-plan should be prepared for the village It should consist of (a) management plan for degraded forests, and (b) yearwise utilisation of resources
- The plan should include
  fodder, fuelwood, timber plantations,
  horticulture plantations,
  alternative sources of energy (biogas, energy efficient smokeless *chullhas,* solar cooker), etc ,
  agro-forestry, silvipasture, agro-horticulture,
  stall feeding of cattlehead, breed improvement,
  water conservation and water harvesting structures,
  moisture control on agricultural land and dryland farming, and
  village level industries etc.
- Such micro-plan should be adopted by the executive body and FPC/VFC

Phase-VII Implementation according to micro-plan

- Responsibilities of FPC/VFC or informal groups
  Control of uncontrolled grazing, encroachments, fires, illegal felling, etc
  Control over exploitation of fodder, fuelwood, small timber and NTFP produce
  Social sanctions or referring the offence to be booked under Forest Act for offenders
  Ensuring equitable distribution of benefits and usufructs
- Facilities available to FPC/VFC
  The FPC and VFC would have total rights over non-nationalised MFP from the protected forests under JFM 30% of nationalised MFP would be under the control of FPC/VFC
  The FPC/VFC would have full rights (100%) over all fodder, foliage, fuelwood, small timber (from thinning) produced from such degraded areas
  30% of timber/fuelwood produced from final felling would be the property of FPC/VFC If they want, the government may allow such income be given in cash to the committee
  It would be the responsibility of FPC/VFC to ensure equitable distribution of produce, benefits or usufructs

JFM committees in watershed

JFM could play a pivotal role in development of watershed areas comprising of degraded forest land in Jhabua, as almost all the milli-watersheds have 20-30% degraded forest land Protection, conservation and rejuvenation of such areas by JFM committees (or by informal protection groups) would ensure sustainability of the watershed project (see Table 19 1) Assisted regeneration and rejuvenation of degraded areas could be accomplished by using following techniques

Table 19.1 *Salient features of JFM approach JFM represents a fundamental shift in the forest regeneration methods and conceptually envisages a movement*

From	*To*
Centralised management	Decentralised management
Revenue orientation	Resource orientation
Production motives	Sustainability
Single products	Multiple products
Large working plans	Micro-planning
Target orientation	Process orientation
Unilateral decision making	Participatory decision making
Punitive rules	Self-abnegation rules
Controlling people	Facilitating people
Department	People's institutions
Assumed homogeneity	Recognising diversity
Achieving single pre-set objective	Fulfilling multiple, need-based objectives
Area management	Site-specific management
Timber production	Multiple products combined with biodiversity
Single technical package	Menus of options
Fixed procedures	Experimentation and flexibility
Plantation as first option	Low input management and regeneration
Single species	Multi-species and multi-tier plantations

I Year

1 Identification of appropriate degraded land within watershed area
2 Preparation of participatory micro-plan(and making it a sub-unit of action plan for micro-watershed)
3 Raising of nursery stock (at WDC level, at women's SHG level or at kitchen garden level)
4 Cutting back the living stocks(February-March-April)
5 Digging of pits and preparation of plantation sites(March-April)
6 Soil and water conservation treatment work like staggered trenches, drainage line treatment etc. (February-June)

II Year

1 Seed sowing techniques on/over trenches Seeds like *Neem, Prosopis, Jatropha*, etc , may be sown (July-August)

2. Preparation of grassbeds on bald patches and sloping terrains (May-June) and pasture development.
3. Planting of seedlings/saplings in gaps followed by weeding and soil preparation (June-November).
4. Singling of coppice shoots, retaining healthy ones.
5 Supportive energy plantation.

III Year

1 Replacement of dead shoots followed by soil working.
2. Grafting or budding of indigenous and wild horticultural tree species (February-March)
3. Cut-back operation (CBO) (October).

IV Year

1 Replacement of dead shoots and soil working (July-November)
2. Removal of unwanted coppice shoots.

Area and climate-specific regeneration techniques could be identified and used The regeneration would provide fuelwood, fodder, foliage, MFP, small timber, etc The resultant tree crop could be from

(i) leading shoots from coppices,
(ii) seedlings naturally grown, and
(iii) seedlings and saplings artificially introduced

The community should ensure 2x2 5 m spacing with an average of 2000-2500 plants per hectare. Tending and harvesting operations should focus on

(i) maintaining the full canopy cover at the relevant/appropriate time,
(ii) quality improvement of the existing stock,
(iii) maintaining sufficient member of secondary species to allow the natural propagation and NTFP collection,
(iv) identifying the secondary coppicing species for sustainable firewood supply,
(v) pruning regime for leaf harvest of important NTFP trees,
(vi) planning space for crown development of various species (Pathan, 1996).

Generally,

(i) space needed for light crown trees would be around 5 m,
(ii) space needed for moderate crown trees would be around 7 m, and
(iii) space needed for bigger crown trees around 10 m

Thus, on an average, 40 sq m per tree would be the size of canopy of mature tree So, selection of 250 trees (except NTFP) from existing 2000 or 2500 plants would necessitate management operations Thus, removal by gradual light thinning may be done as follows

1st year = over 2000
5th year = 2000 (2 x 2 5 m)
10th year = 1000 (4 x 2.5 m)
15th year= 500 (4 x 5 m)
20th year = 250 (8 x 5 m)

The thinning operations should be light and selective Healthy and genetic-plus trees should be retained Overcrowding should be avoided in all sectors of the field Trees like bamboo, *prosopis*, *nilgiri*, etc , should be taken up or retained in certain blocks or pockets, so that, they do not adversely affect the growth of other species Nearly 25 fruit bearing trees like *mahua, amla,* mango, etc., should be retained till the last felling Similarly, NTFP species should be retained Fodder, herbs/shrubs should be retained for biomass and biodiversity.

The committee or informal group should monitor the management of such degraded forest areas. PRA techniques like scoring matrix, etc, may be used The monitoring should be at least on following parameters

(a) need analysis,
(b) site quality,
(c) people's participation in planning,
(d) people's participation in execution,
(e) control of biotic influences,
(f) biomass and biodiversity,
(g) local ecology,
(h) productivity of fodder, fuelwood, NTFP, small timber, and
(i) benefit sharing

Since, natural regeneration is far more cost-effective model than plantation, hence, plantation activities should only be taken up in a watershed where there is no/or negligible natural regeneration from the root stock

Problems or conflict situations

Protection, conservation and regeneration of degraded forests bring multifarious benefits to the community in a watershed area Multitude of conflict situations would appear from third and fourth year onwards, which should be addressed and resolved by the Watershed Development Committee (WDC), Watershed Association (WA), and Project Implementing Agency (PIA) Problems which would arise are

1 Neighbouring villages (other than the one involved in protection), who were dependent on the same patch of forest, start demanding a share in the usufructs
2 Vested interests within FPC or informal groups may try to sabotage the programme and may try to illegally procure most of usufructs
3 Marketing of many MFP like lichens, gums, raisins, seeds, flowers, mushrooms, etc, may create difficulties and problems
4 Varied utilisation pattern of certain produce and preferences among different sections of the community may raise conflicting situation. There may be clash of interests among various groups to use young *bhabbar* grass as fodder or mature *bhabbar* as fibre cash crop Similarly, a conflicting situation may arise among various groups to use young bamboo for handicraft or mature bamboo as building material
5 Generation of substantial quantity of fuelwood and fodder would be possible Conflicting situation may arise when a particular group prefers to use it in their household and others prefer to sell them in open market or nearby villages for small amount of cash
6 Adoption of new silvicultural practices and techniques would create hurdles, as the preferences for new species would vary.
7 Due to lack of information flow, suspicion and rivalries may arise among various groups
8 Forestguard, foresters, deputy range officers, etc. may create obstacles, confusions,

hindrances and confrontations due to their overpossessive attitude towards resources

9. Community members who are not represented in the executive or decision-making body of the committee or the group may feel left out leading to distancing
10. Dominant castes or groups may try to take over the management within their hands
11. Confrontations with panchayats over the issue of *nistar*.
12. Village committees do not easily understand the intricacies of the calculations (like variable costs/fixed costs involved in the protection), as a result transparency and satisfaction of beneficiaries cannot be ascertained at the time of sharing of usufructs.
13. Sanctions imposed on violators may create heartburn, specially among cattle herdsmen, women carrying headloads, etc This may cause friction and rivalry among various groups
14. Nomadic groups like *Rabbaris, Banjaras*, etc , may try to extract certain produce (especially fodder, fuelwood, NTFP) for their use This may create conflicting situation and can lead to law and order problem
15. Studies have indicated that marginal and low income groups and women have a higher dependence on forest produce (Malik, 1994, SPWD, 1995). The impact of protecting a forest has differential impacts on different sub-groups within the community JFM may try to marginalise such groups
16. Micro-plan prepared for JFM may not coincide and corroborate with action plan for watershed development This may create conflicts between PIA/WDC/WA and FPC/VFC/ informal groups.
17. Encroachers on degraded forest may try to take back possession by legal method or by use of force.
18. Usufruct sharing may not be transparent and can create factions within the committee or group

Role of NTFP in JFM

Community has access to numerous NTFP, even from degraded forest areas Produce like bamboo, resin, *lac, kattha,* canes, tendu leaves, sal leaves, sal seeds, *mahua* flowers, *sabai* grasses, *rosha* grasses, medicinal herbs, *tassar* silk cocoons, medicinal plants, honey, fruits, etc , are easily available The relative importance and availability of each NTFP varies from one region to the other. The regular flow of NTFP and income so generated is more than a one time benefit from timber, which would only be available in the distant future The certain and regular flow of NTFP retains the interest of the community in the JFM. NTFP starts flowing from the first year of forest protection, their volumes and composition slowly changes as the degraded forest regenerates

NTFP are used for daily subsistence and cash needs and are useful in religious and cultural ceremonies NTFP-based activities are household-based, labour-intensive, accessible to the most disadvantaged section, use simple technologies and usually do not involve high capital inputs NTFP are often the only resource accessible to the poor and marginalised groups within the community

NTFP are an important source of food, especially for the disadvantaged and marginalised sections of the community It has been reported that about 30% of the diet of tribal groups living near forests in Maharashtra is derived from forest products (World Bank, 1993). In Bastar district, 75% of the people dependent upon forests supplement their food by tuber, flower and fruits all year round. Dependence on NTFP is much greater during drought years and NTFP works as an insurance against famine As much as 75% of rural population use fuelwood for cooking purposes. Fuelwood is an important source of income for BPL families, especially during the lean agriculture season.

NTFP, in most areas, are a major source of livelihood. The women have NTFP collection from forest areas as their primary occupation. It was found that households having an annual income of less than Rs 3000 derived 50% of their earnings from NTFP, whereas those earning over Rs 6000 derived 21% from NTFP (Malik, 1994). The contribution of NTFP to family incomes averaged 20% in tribal households (Malhotra et al., 1991)

FPC can exclude outsiders from the protected area and thus enjoy full benefits of products regenerated from protection efforts Nationalised/monopolistic NTFP are excluded.

Gender and equity issues in JFM

JFM offers immense opportunities for empowering the forest dependent and marginalised women and men to gain increased access to, and control over the management of common pool forest resources to improve their well-being, livelihood and standard of living

Equity connotes fairness by reducing instead of perpetuating or increasing existing inequalities. Prescription of 'equal shares' of usufructs for people in grossly unequal circumstances is not highly inequitable Due to the dynamic hierarchy of social and power relations among different groups, it is often the powerful non-users of forests who have the greatest visibility and voice Thus, a correct identification of the forest users within the households and communities should be made by desegregating them in caste, class, ethnicity, gender groups, etc This could be first step in implementation of JFM This participatory programme needs to be sensitive to gender disparities and to constraints which prevent women from participating as equals Hence, emphasis should be laid on reorganising and strengthening their customary rights to common forestry resources, of which they are major users

One-third of all households are solely supported by women, and in another third 50% of the earnings are contributed by women (GOI, 1995) The poorer the family, the more it depends for its survival on the earnings of its female members (World Bank, 1991) Mostly, women have multiple, often disproportionate responsibilities, they have little ownership or control over resources This imbalance in the ownership and control over resources relative to gender responsibilities place women on subordinate and dependent position Hence, JFM approach in watershed areas should try to facilitate long-term changes in gender relations based on more equal distribution of resources and responsibilities and power and authority between men and women

Women are also not a homogeneous category Different groups of women within the same community may have different and conflicting forest management priorities and perceptions In a broader term, JFM is inherently 'anti-feminist' or biased against women.

1 Women from marginal landholding households and landless have to put manifold increased labour and time for firewood collection from distant areas (Sarin, 1994).
2 Poorer women are forced to switch over to poor quality, less efficient fuels like leaves, bushes, weeds, dung, etc This increases the time to cook the food and can be damag-

ing to health and environment.

3. Loss of primary source of livelihood to poorer women.
4. Adverse impact on artisans such as potters, blacksmiths, carpenters etc. (Roy, 1994).
5. Adverse impact on household earnings due to decreased part time employment avenues based on forest products.
6. Increased tension and conflict with other village groups on fodder and fuelwood collection.
7. Decreased access to NTFPs.
8. Higher caste and better-off women, who are less dependent on forests, are forced to pressurise and humiliate poorer women (Sarin, 1995 and 1996).
9. It may initiate and culminate into armed fights over access to source of livelihood (Singh, 1996).
10. Lack of alternative employment may force them into 'mass loots' of regenerated forests under community protection (Mukherjee, 1995).

JFM in watershed areas should have following rules implemented.

1. at least one-third of local institutions managing committee members, as well as the office bearers should be women (it should be 50% where the women are the predominant forest users),
2. the women managing committee members should be selected by women forest users,
3. all managing committee members and office bearers should be forest users, and
4. proportionate presence of forest users/female members should be mandatory for the quorum to be complete (Madhu Sarin, 1996).

The gender equity can be assured by.

1. Use of holistic PRA techniques, which provide voice and decision-making authority to landless, resource-poor and women (Hiremath, 1996)
2. 30 to 50 percent women attendance must be mandatory for completing the quorum for local institutions
3. Empowerment of women groups by developing them as credit and thrift groups (like *Baira-ni-Kuldi* in Jhabua) with assistance from DWCRA, SHG revolving fund (from watershed) and SHG financing schemes of NABARD Such powerful groups would give momentum to women's role in JFM.
4. Encouraging male leaders to promote respect for women's equal rights and their active participation in decision-making would make JFM attuned to gender issues
5. Gender-biased traditional and customary practices could be changed by facilitation
6. At least one project assistant *(Pariyojna Sahayak)* with PIA should be a woman. They should be authorised to facilitate and catalyse such process
7. Keeping track of absent women members from all kind of meetings Absence may be due to unawareness about the meeting, inconvenient time of the meeting, inconvenient place of the meeting, feeling that attending such meetings are not worthwhile and socio-cultural constraints
8. Emphasis should be on understanding variable needs and priorities of women groups than on sensitising them about the importance of conserving forests
9. External facilitators can empower women groups Women and marginalised communities can gain voice in decision-making through equitable, alternative management

options based on desegregation of local needs by gender and socio-economic status (Madhu Sarin, 1996)

10 Women of all classes and men of disadvantaged groups remain excluded from behind-the-scene bargaining and negotiations, which are attended by powerful male interest groups So, apparently participatory village meetings are often held simply to get public ratification of the decisions that have already been taken by coterie Hence, facilitator should give a serious look into the power dynamics, both of class and gender, among different interest groups during meetings and discussions.

11 Organising separate meetings with women sub-groups

12. Promotion of separate women organisations would inculcate leadership qualities and communication skills In Jhabua, *Mahila SAJHA Manch*, (for literacy), *Baira-ni-Kuldi* (for crediting and thrifting), *Sharab-Bandi Morcha* (for prohibition), 'green' SHG (for nursery raising) have helped in highlighting collective voice of women groups.

13 Women groups should be aligned with other grassroots institutions like panchayats, *Bees Sutriya Samiti, Gram Surakhsa Samiti, Mahila Samakhya Samiti*, etc

Only by encompassing gender issues in JFM implementation, the Government of India's forest policy dictate "massive people's movement with the involvement of women should be created to achieve the policy objectives," could be fulfilled

JFM and watershed development

JFM is a shift from totally state controlled forest management to decentralised, participatory and local need-based co-management Watershed development (WD) is a decentralised and participatory co-management of all kinds of resources To that extent, broadly, JFM could be considered as a subsidiary sub-unit of watershed development The processes and procedures are common in JFM and WD Similarly, both these programmes aim for individual growth, community development and resource enrichment Considering the similarities in target groups, techniques and processes, goals and objectives, JFM could be fabricated and enshrined into local schemata of watershed management. In Jhabua district, JFM has been used as a vehicle programme on which watershed development projects have been launched Based on the Jhabua experience, following types of interactive management systems could be adopted in watershed areas:

Strategy-1

All Watershed Associations (WA) are co-terminus with FPC/VFC and all Watershed Development Committees (WDC) are basically executive body of FPC/VFC All the authority and responsibility bestowed on WA and WDC in watershed guidelines is handled by FPC/VFC and executive body Project and development accounts and their records are managed by FPC/VFC This strategy is adopted in watershed areas where JFM is very strong and organised and where most of wastelands are degraded forests

Strategy-2

Three to five members are common in JFM executive body and WDC President of FPC/VFC executive body is ex-officio member in WDC and *vice versa* Joint monthly meetings of WDC and FPC/VFC executive body are held regularly Common minimum programme is evolved and is encompassed into action plan. This strategy is adopted in watershed areas with moderately successful JFM and where 15-30% of wastelands are degraded forests.

Strategy-3

The Divisional Forest Officer (Territorial) is appointed as additional project director of all watershed activities in the district. Range or deputy range officers are necessarily be there in MDT at milli-watershed level Forest guards or foresters are involved in planning, execution and monitoring of watershed action plan in micro-watershed This strategy is adopted in watershed areas where JFM is a new concept, where informal protection groups are involved in protection of degraded forests and where 5-15% of wastelands are degraded forests.

A definitive and area-specific model should be evolved in every district to integrate and assimilate JFM in a bigger paradigm of watershed development.

●

20

Common Property Resource Management in Watershed Areas

Common property resources (CPRs) can broadly be defined as resources in which a group of people has co-equal user rights Membership in the group of co-owners is typically conferred by membership in some other group, generally a group whose central purpose is not the use or administration of the resources In India, these resources include community pastures, community forests, wastelands, common dumping and thrashing grounds, watershed drainages, village ponds, rivers, rivulets, etc Even when the legal ownership of some of these resources rests with another agency or agent, in *de facto* they belong to the village communities and continue to be a significant component of the land resource base of rural communities

CPRs are those resources in which a group of people or the villagers have co-equal user rights and they manage, maintain, utilise, protect and construct these resources with equal right and responsibility May be due to incidental reasons, title or legal possession of these CPRs are given to an outsider or individual, but the community remains the sole user of these CPRs CPRs like community forests, community pastures, wastelands are spread over a large area, so they play a pivotal role in livelihood of the community or the village Personal property resources (PPRs) have become important *vis-a-vis* CPRs in developed countries, still CPRs have unique and important place in developing countries Even after catering to multiple needs, CPRs are facing crisis unlike in rich developed countries They are now threatened by neglect, overexploitation, underinvestment and expropriation CPRs are among the most neglected areas in development planning To all but the poorest, they are almost invisible There have been plethora of micro-level evidences on the contribution of CPRs to poor people's livelihood, their steep decline in area, productivity and production over the last 40 years, collapse of traditional management systems and the consequent pauperisation of the poor

After analysing the composition, development, utilisation, conservation and management, the following salient features of CPRs come to focus

1 CPRs are formed from amalgamation of land, forest, water, soil and many other natural resources

2. CPRs are a central focus point of the livelihood and lifestyle of the villagers. They contribute in their agriculture production, livestock management, non-farm activities, rural industries, etc.
3. Everyone in the community has access to these CPRs. But this does not mean that there are no sanctions.
4. Social organisation of the villages may not be effective and efficient in management, conservation, regeneration and utilisation of CPRs.
5. Community understands and believes that CPRs are for them and they are not for CPRs

Role of CPRs in rural livelihood

CPRs are categorised into natural and man-made. These are described as under:

Natural CPRs

These are nature-gifted and include:

(a) *Land resources*·

- (i) *Gochar* (plot of land left vacant for livestock grazing)
- (ii) *Banjar* (degraded and wastelands, under individual or group ownership but used as resting place by livestock of the community).
- (iii) *Gaura* (plot of land where milking of milch cattle is done)
- (iv) *Khaliyan* (land where all the members of the community store their crop produce together)
- (v) *Nistar* (land reserved and left vacant for fairs, haat markets, cultural ceremonies etc.)

(b) *Forest resources*

- (i) *Kakad bani* (plot of land with vegetative cover specially between two village boundaries).
- (ii) *Devbani* (plot of forest land left by the community in the name of god and used only in the event of natural crisis/disaster)
- (iii) *Rakhabani* (plot of forest land left by consensual decision of the community, used as the last resort).
- (iv) *Devaranya* (plot of forest land for god).
- (v) *Waal* (forest land owned by *zamindars* or temples, may be used for cultivation)
- (vi) *Beed* (mostly private dense forests used by the community at the time of crisis)
- (vii) *Rundh* (private dense forests which could be used by the community after paying taxes).

(c) *Water resources*

These include ponds, tanks, bunds, checks, wells, canals, rivers, rivulets, etc

Man-made CPRs

These are created by the community for the community and include

(a) village tanks,
(b) *bavdi* (traditional ponds),
(c) bunds/dams,
(d) wells,
(e) *chaupal* (for community meeting),
(f) *thanie* (platform for judicial meetings),
(g) waterways, field channels,
(h) paths, roads,
(i) schools,
(j) playgrounds,
(k) cemetery,
(l) temple or worship place, and
(m) *dharmshala* (community building).

Although CPRs contribute to people's employment, income generation and asset accumulation, they are seldom recognised and recorded, especially in the case of long-term social and ecological processes characterizing dry areas CPRs principally provide

(1) *Physical products* such as food, fibre, fodder, fuel, timber, water, manure, silt, space, etc

(2) *Income and employment opportunities* such as off-season activities, drought period sustenance, additional crop activities, additional animals, petty trading, rural industries, handicrafts, etc

(3) *Larger social and ecological gains* such as resource conservation, drainage/recharge of farming systems, renewable resource supply, better micro-climate and micro-environment, etc

Table 20.1 *Extent of dependence of poor and wealthy households on CPRs in dryland India*

State	*Household category*	*CPR contribution*			
		Income %	*Fuel supplies* %	*Animal grazing* %	*Days of employment per household*
Andhra Pradesh	Poor	17	84	—	139
	Wealthy	1	13	—	35
Gujarat	Poor	18	66	82	196
	Wealthy	—	—	—	—
Karnataka	Poor	20	—	83	185
	Wealthy	3	—	29	34
Madhya Pradesh	Poor	22	74	79	183
	Wealthy	2	32	34	52
Maharashtra	Poor	14	75	69	128
	Wealthy	1	12	27	43
Rajasthan	Poor	23	71	84	165
	Wealthy	2	23	38	61
Tamil Nadu	Poor	22	—	—	137
	Wealthy	2	—	—	31
Jhabua	Poor	34	89	94	198
	Wealthy	11	71	39	89

CPRs contribute and allow considerable access to all users, but not all the sections of the rural community are equally attracted by these potentials and opportunities (see Table 20.1).

The proportion of poor households dependent on fuel, fodder and food items from CPRs ranged between 84-100% in different villages. In general, the rural poor obtain the bulk of their fuel supplies and fodder from CPRs Income from CPRs accounts for 14-23% of household income from all other incomes and they form an important source of income and employment, especially during the periods when other opportunities are almost non-existent. CPRs complement private farming by providing crop inputs, sustaining animals and are especially predominant in drought.

In Jhabua, 34% of household income and 51% of total employment in a year is provided by the CPRs. They sustain 46% livestock and farm animals. Relying solely on private land would imply a reduction in available farmyard manure by 46-53%. The income and employment generation in drought years from CPR may increase CPRs help in filling the resource and product gaps faced by private resource-based farming PPR-based farming in the dryland context of Jhabua could thus be strengthened by revitalisation of CPRs through watershed interventions.

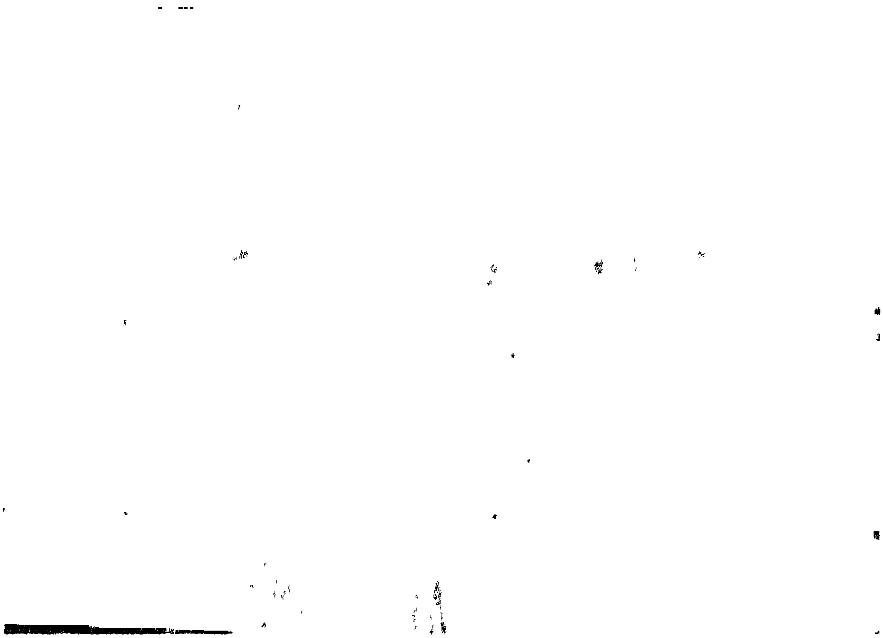
Depletion of CPRs

Despite their multifarious and valuable contribution to the rural economy, CPRs are the most neglected in development planning (see Plate 54). The formal invisibility or non-recognition of their contributions has led to disregard of CPRs by development programmes and regulatory policies. This neglect has reduced the area in official and semi-official records. The decline in productivity and production is more difficult to measure, as the records of CPRs based on production criteria were never maintained The reduction in area and the productivity has in turn induces further fall in their pay-offs followed by further neglect and degradation Following are some of the factors causing deterioration and depletion of CPRs·

(a) *Government policies* In 1960s and 1970s, the government decided to launch 'green revolution' in remotest corners of the country. But the delivery system increased the agricultural area at the cost of CPRs Many community lands were declared *Kabil-Kasth* and were allocated to landless. Long-standing encroachments on revenue or forest areas were regularised by providing *pattas* (legal rights) of those plots. This practice accelerated privatisation of CPRs There has been an increasing tendency due to government policies, to encroach on government land/community land Those who could not manage land from excess land under land-ceiling acts and *bhudan*, were forced to encroach on community forests/pastures, wastelands for cultivation. Quite frequently, well-to-do and rich farmers manage more land by adopting above methods Hence, the distribution of land *pattas* under development programmes and regularisation of encroached revenue and forest lands resulted in atomisation of 'commons'

(b) *Government programmes to increase productivity* Certain innovative and welfare measures adopted by the government to increase the productivity of CPRs resulted in negative fallouts In 1950s, social forestry was emphasised and numerous interventions like community forest, *panchvan*, tree-cooperative schemes were tried on CPRs Due to

Plate 54 *Uncontrolled grazing and large cattle population in a village devastate and degrade go-char lands and CPRs*



low or negligible community involvement, cooperation and participation, the community did not own the programme after implementation. Similarly, the technologies adopted (say land development, soil and water conservation measures in NWDPRA etc.) were not adapted from or not suited to prevalent and commonly accepted indigenous technologies. Due to lack of appropriate technologies and failure in capacity-building of the community, the CPRs remained demonstration or commercial plots, with the community getting alienated from interventions in CPRs.

(c) *Failure of PRIs.* Panchayat raj institutions (PRIs) like Gram Panchayats were bestowed with responsibility to maintain and manage CPRs. As the villagers, illegally possessing CPRs formed vote banks, the PRIs could not utilise the opportunity to enforce CPR-related regulations. The local and traditional *Jaati Panchayats* (caste panchayats) also lost the credibility and authority due to their negligence. The encroachers acted as a pressure group against eviction of illegal possessions on CPRs. Even now, PRIs find it difficult in Madhya Pradesh to evict encroachers (though revenue laws give them explicit authority after amendment in MPLRC in 1990s). The Gram Panchayats are interested to get CPR lands declared as *abadi* (residential) land, so that they can indiscriminately allot residential *pattas* to other villagers. The dependence of panchayats on community votes compel them to avoid unpopular steps like enforcing CPR-rules and legislations. Nomination of influential groups with little interest in CPRs make these new institutions ineffective (Jodha, 1985, Gupta, 1987). The panchayats always look up to the government and administration for government grants for CPRs. The fault on the part of the panchayat has thus converted CPRs into open access resources with the tragic consequences. Village elders or traditional panchayats had informal authority in managing the CPRs effectively (Brar, 1987)

(d) *Faulty education*: The present education has almost totally alienated the educated youths from their traditional management systems, indigenous skills and knowledge, common property resources and environment. The education is too individualistic to leave scope for community and ecological development. The education system failed to highlight the importance of CPRs in rural livelihood pattern. This has created apathy in the minds of rural youths regarding CPRs.

(e) *Distribution in society*: Market forces, financial and industrial changes and global communication has destabilised the community or cooperative schemata of options Joint families disintegrated into nuclear families and distances between households increased. In place of contributing in managing community grasslands, farmers started preferring cultivation of fodder or forage crops in their fields. Fuelwood demand from community forests is not fulfilled, so agro-forestry is adopted to meet the individual demands. Personal preferences, motives and beliefs are dominating the psyche of rural population This has grossly demolished the capacity of the community to unite together and manage the CPRs The acquisition of CPR responsibilities by the government has forced the community to move further away.

(f) *Biotic pressures*. The indiscriminate increase in human and livestock population has pressurised CPRs The demands for water, fuelwood, fodder, small timber, food, etc, have risen to exorbitant levels.

The ICRISAT survey in 1982-85 in 82 dryland Indian villages revealed that CPRs have declined since 1950-52, the time of comprehensive land reforms in India CPRs declined by at least 30% and in some cases by more than 50% in last 40-odd years In Madhya Pradesh, the present average area of CPRs per village is 1435 ha, which has caused atleast a threefold increase in the number of people per hectare of CPR land For example, in Madhya Pradesh, the number of persons per hectare of CPR, which was 1 4 in 1951, increased dramatically to 4.7. Public policies for raising CPR productivity have both lacked an appropriate focus on CPRs and have over-focussed on production technologies (Gupta, 1987, Jodha 1988) Alien technologies were introduced, which over a period of time were rejected by the community There was little institutional sensitivity and orientation in these policies to raise the productivity of the CPRs involved. In several cases, the community lands were alienated from the people and transferred to pilot projects of demonstration plots In social forestry projects, community lands were converted into commercial plots Also in last few decades, resource-crunch state has tried to grab resources from more productive CPRs by monopolising collection or marketing The major indicator of physical degradation is the drastic and sharp decline in the number of products that villagers gather from the 'commons'. Species diversity has declined and species mix has changed. The productivity and returns per hectare from CPRs has also declined

There was a well-established and well-entrenched traditional management system under operation for centuries The community was managing, maintaining, regulating, conserving and utilising CPRs The salient features of the system were·

- traditional management system in CPRs do not infringe on natural cycle and forces,
- equitable and equity in distribution,

- community planning, implementation and monitoring,
- optimal exploitation of benefits from CPRs, and
- the products from CPRs used for personal consumption and not for commercial utilisation

The traditional management system ensured implementation of community rules and regulations in resource utilisation, adoption of conservation principles and equity and equitable distribution of produce. Presently, in the absence of usage regulations, overexploitation of CPR has increased. The inability to enforce obligation in CPR in terms of grazing tax or compulsory labour input has led to their poor condition. These failures have resulted from abolition or complete collapse of the traditional formal or informal management systems for CPRs (Jodha, 1985, Chambers et al., 1989; Roy Burman, 1986) Compared with the early 1950s, only 10% of villages regulate grazing or provide watchman, none of them levy grazing taxes or penalties/sanctions for violation of regulations Only 10% have user-obligations for maintenance and repair Certain institutional reforms, such as the introduction of land reforms and new panchayat systems have been introduced. The former led to abolition of a number of levies and taxes on CPR users and the later undermined the traditional informal authority of village elders and replaced the formal authority of feudal landlords or dominant castes In the traditional management system, community used to decide the utilisation of CPRs Since the users of the CPRs and the decision-makers were same, all the decisions were in the interest of everyone in the community The community had moral authority to inflict sanctions on the violators Unwritten code of conduct and regulations were prevailing in the villages Increase in biotic pressures could not demolish CPR systems, as the community modified the terms for exploitation But, unfortunately, economic development, forest and land related enactments, modernisation of agriculture, etc, distorted the vision and demolished the community-based CPR management systems (Plate 55 a, b)

From disintegrating CPRs the rural rich have withdrawn from CPR use, as their opportunity cost of labour for collecting and marketing/using CPR product was higher than the returns from the CPR products (Jodha, 1986) They also increased their reliance on alternative options (Stewart, 1989), like new biomass products. They substituted renewable CPR products by non-renewable and/or external products (like stone fencing from biological fencing or rubber tyres for wooden wheels for bullockcarts) The big landholders considered CPRs as personal assets, and they grabbed CPR lands, prevented others from using them during off/lean season and enriched their own soil by taking away productive topsoils from CPR lands to their private fields (Jodha 1986, Iyengar, 1988) They grew indifferent to the management of CPRs despite their influence and ability to use legal-cum-administrative superstructure and public funds (grants/subsidies) The rural poor continued to utilise CPRs as an important source of sustenance and due to paucity of alternatives they readily accepted increasingly inferior options offered by CPRs The landless or PPR-poor families increasingly restored to measures manifesting a high degree of desperation, such as, increased frequency of premature harvest of CPR products, removal of plants and bush roots, use of poor alternatives like discarded and inferior products and overcrowding and overexploitation of CPRs.

Loss of CPRs have resulted in an acceleration of the pauperisation process The functions of CPRs are threatened and their contributions to poor people's livelihood have declined The decline in the quantum and quality of CPR has resulted in increased unsus-

Plate 55 (a, b) *Social fencing is an ultimate aim in CPR management Till the time this is achieved, cost-effective cattle proof walls (CPW), with or without vegetative barriers, may be taken up*

tainability of land-based activities in dry regions The progressive decline in the value of CPR products, accompanied by equally increasing number of people relying on them for sustenance, has pauperised the community

CPR management in watershed programmes

Management of CPRs is an important priority sector in watershed development The emphasis is to reactivate the traditional informal management systems for CPR in watershed areas The Jhabua model of Integrated Watershed Development Project has used the vehicle of such informal systems As mentioned earlier, informal groups protecting, conserving and utilising CPRs (like pastures, vegetations and wastelands in degraded forest areas) were restrengthened A new energy and dynamism in the form of JFM was introduced in them It was consciously tried not to suffocate local initiatives by imposing plethora of JFM regulations The physical and legal-cum-administrative interventions were focussed and sensitised with CPR perspective Due to extensive exploitation of the CPRs, Jhabua has, over a period of years, been converted into verified degraded dryland with massive soil erosion and runoff WA and WDC have been given primary role in accentuating the process of CPR management Enrichment and regeneration of CPR was planned, executed, managed, maintained and utilised by the WA in watershed areas Institutional management in the form of formulation of numerous effective UGs and SHGs has resulted in a major change in the perception The users were made managers (for example, fishermen's UG for fishing tanks, water UG for irrigation tanks (Plate 56), VFC for degraded forests, handicrafts UG for non-farm activities, etc) The community is mobilised and encouraged to

Plate 56 *Making most of available water body pisciculture by organising fishermen SHGs is one of the main ways to generate additional income*

participate in CPR management by launching comprehensive multimedia campaign. The WDP ensured·

1 fewer occupational changes (that is, say shift from handicrafts to cultivation),
2 promotion of occupations which can be supported by the existing CPRs,
3 less factionalism in the village, implying greater degree of social cohesion, conducive to the protection of CPRs,
4 less patronisation of UGs/WDCs involved in CPR management, so as to decrease outside influences on the management system and decreasing the dependence on external influences,
5. equity of access and benefits from CPRs and ensuring equal stake in the maintenance of CPRs (see Plate 57),
6 create forum for the community to evict CPR-grabbers,
7 promote indigenous and appropriate technology for CPR management, and
8 inculcate the feeling and atmosphere for cooperation and cohesive action.

At the planning stage, the DRDA or the WAC has to earmark the approach of the programme

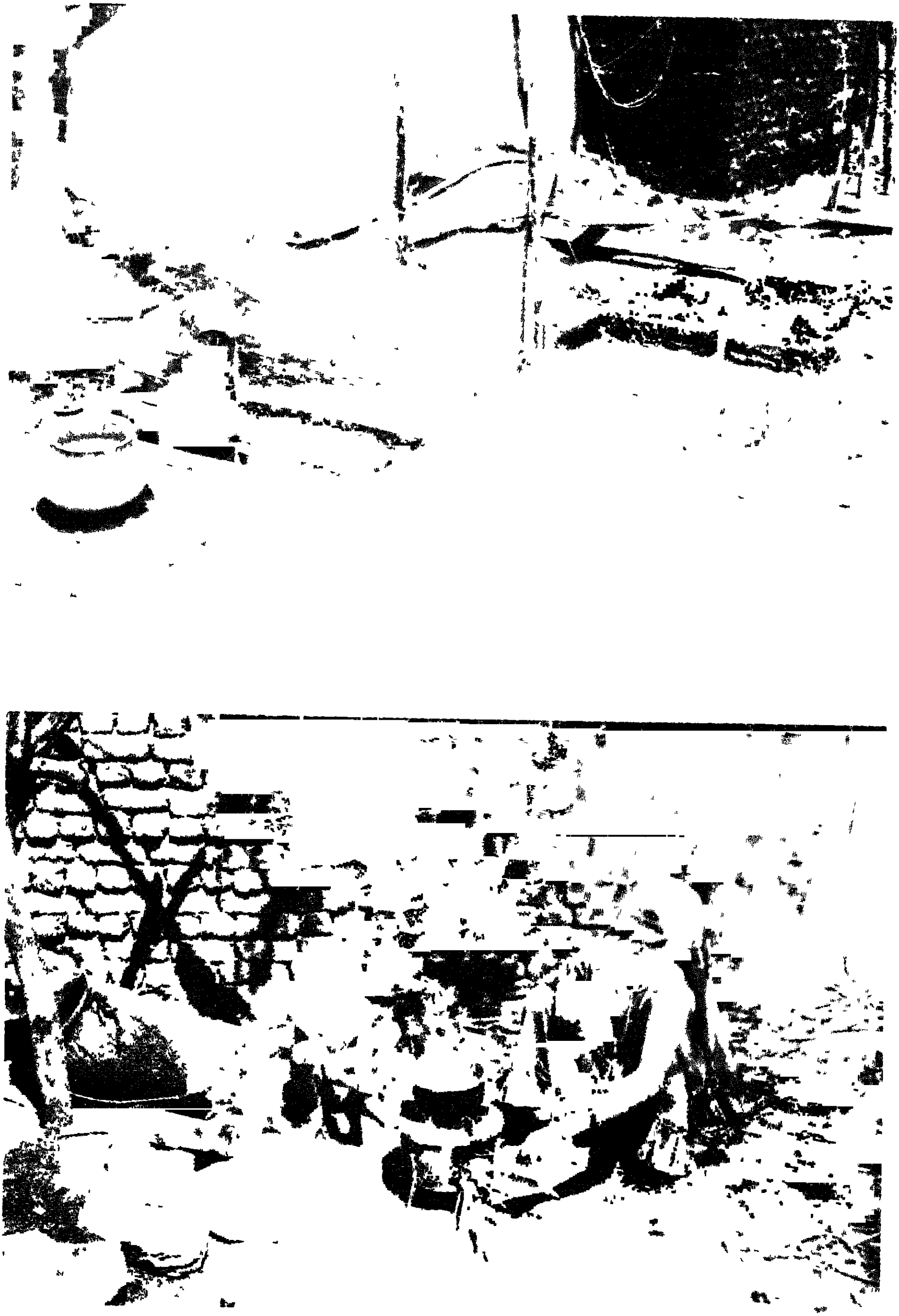
(1) *Investment needs*: For sustained and effective management of CPRs, increase in their productivity is essential. This requires rapid regeneration, through protection and regulated use and provision of substantial investments into CPRs

(2) *Positive approach*: Positive interventions, decided with the community, restricting the further decline of CPR areas, should be the major component of CPR development.

(3) *Technology focus*: The rehabilitation of CPRs as productive social assets need a

Plate 57 *For women SHGs, collection of MFPs in different seasons provides livelihood support*

Plate 58 (a, b) *Introduction of low-cost, energy-efficient biogas plants and smokeless sigris/chulhas in watershed villages reduce fuelwood pressure on CPRs*



new technological focus in terms of species, inputs and technical methods of resource management Besides productivity, emphasis on diversity and usefulness of products should be highlighted (see Plate 58 a, b)

(4) *Management and regulations*· It should be well understood that the rehabilitation of CPRs is less of an investment-cum-technological problem and more of a resource management problem This cannot happen unless the CPRs are re-converted from 'open access resources' to 'common property resources'. In operational terms, usage regulations and user obligations towards CPRs should be re-established.

(5) *Traditional practices*: Traditional practices regarding management, conservation, and utilisation of CPR may be useful or harmful for the CPRs Practices which positively promote CPR rehabilitation should be encouraged while others should be discouraged. The process has to be participatory and slow, and should be handled with proper sensitivity. The traditional institutions should be revived and interwoven properly into the CPR management system.

(6) *User groups* The basic institutional arrangement to fulfil the objectives, could be formation of CPR-user groups There are no unique methods to promote such groupings The pattern of UG depends on the type of CPR and village-specific conditions Uniform or static pattern should never be promoted The key features of CPR-UG should be

— equity of access and benefits from the CPR for all its members,
— UGs should have legal sanctions, but should remain outside the control of formal village institutions,
— membership of the group should include the whole village, community or specific occupational groups,
— a pre-condition for group membership should include a binding commitment to user obligations and regulations, and
— flexibility in exit and entry of members should be allowed, with no right to break-up the group

The grassland and degraded forest management, wasteland management, water conservation and harvesting management are some of the important arenas of CPR management in watershed areas The success of recent initiatives in the CPR management, specifically in watershed areas, inspire considerable hope for effective CPR management

21

Empowerment of Women and Other Gender Issues

What is gender? The word was used by Ann Oakley et al in 1970s to describe those characteristics of men and women which are socially determined Essentially, the distinction between sex and gender is made to emphasise that everything women and men do and everything expected of them (with the exceptions of their sexually distinct functions like child-bearing and breast-feeding) and changes over time and according to changing and varied socio-cultural factors People are born female or male, but known to be girls and boys, who grow into women and men They learn about the appropriate behaviour and attitudes, roles and activities, means and ways to relate to other people This learned behaviour forms gender identity and determines gender roles Gender roles for women and men vary greatly from one culture to another and from one social group to another within the some culture Race, age, class, caste and economic circumstances influence the role and status of both women and men As culture is dynamic and socio-economic conditions change over time, hence gender identity and patterns change with them As societies become more complex, the roles played by men and women are not only determined by culture but by socio-political and economic factors Understanding gender differentiation and gender discrimination helps us to understand all the complex ways in which society categorises people into female and male roles and of the ways these roles can be the basis for cooperation and conflict

The concept of gender relation sought to shift attention away from looking at women and men as isolated categories to look at the social relationships through which they were mutually constituted as unequal social categories Gender relations are an aspect of broad social relations, are constituted through the rules, norms and practices by which resources are allocated, tasks and responsibilities are assigned, value is given and power is mobilised (Kabeer and Subrahmanian, 1996) Gender relations take account of the central issues of power and hierarchy within the society Women perform different tasks for the household, earn income in diverse ways, have different levels of control over their respective incomes, allocate time differently, have different legal and traditional rights and possess different kinds of skills and knowledge In most cultures, while women have multiple, often disproportionate responsibilities, they have little ownership or control over resources (such as land and property, education, technical skills and market information) This places women in a subordinate and powerless position relative to men.

The roles played by women in any given society and their status depend upon the legislation, religious norms, economic status, cultural values, ethnicity, types of productive activities in the community and household Women are usually responsible for domestic work like care of children, family health, cooking, providing food and other social services. In most societies they also play a major role in the productive activities of the family like farming, domestic labour, services, income-generating activities, etc In certain communities, they also have clear community roles Women's roles encompass work in following categories.

(i) *Productive works*: Involve the production of goods and services for consumption and trade (farming, fishing, self-employment) Often, women's productive work is less visible and less valued than men's

(ii) *Reproductive works*. Involve the care and maintenance of the household and its members including bearing and caring for children, food preparation, water and fuel collection, shopping, housekeeping and family health care Such manual, labour-intensive and time-consuming tasks are almost always performed by women

(iii) *Community works*. Involve the collective organisation of social events and services, ceremonies and celebrations, community improvement activities, participation in groups and organisations, local political activities, etc These works are important for cultural development of the community and act as a vehicle for community organisation and self-determination

Women's workload in above mentioned works may prevent them from participating in development projects There is a wide gap between women's high (yet unorganised), economic participation and their low political and social power The most important task in a developmental programme like watershed project is to identify practical and strategic gender needs.

(a) *Practical gender needs* They are a response to an immediate perceived necessity, formulated from concrete conditions, derived from women's position within the gender division of labour They are needs shared by all household members, yet identified specifically as practical gender needs of women, as it is women who assume responsibility for meeting these needs They may include needs for water provision, income earning for household health, housing and basic services, family food provisions, etc

(b) *Strategic gender needs* These needs challenge the nature of the relationship between men and women and they aim to overcome women's subordination They may include needs for access to credit and other resources, freedom of choice over child bearing, abolition of sexual division of labour, alleviation of the burden of domestic labour and child care and the removal of institutional discrimination such as rights to own land or property. Due to their relative different situations, women and men have different perceptions, goals and priorities And development interventions affect them differently

Gender and development

There are different forms and levels of equality that constitute development Following are five different levels of equality as the basis for criteria to assess the level of women's development in a watershed programme.

(a) *Welfare*· The level of material welfare of women, relative to men,in such matters as food supply, income and medical care. This level of equality is concerned purely with relative level of welfare and is not concerned with whether women are themselves the active creators and producers of their material needs; such involvement would suggest a higher degree of empowerment and development.

(b) *Access*: Women's access to the factors of production on an equal basis with men: equal access to land, labour, credit, training, marketing facilities and all publicly available services and benefits on an equal basis with men Here, equality of access is obtained by ensuring the principle of equality of opportunity, which typically entails reform of the law and administrative practice to remove all forms of discrimination against women.

(c) *Conscientisation*· Conscientisation involves a belief that the sexual division of labour should be fair and agreeable to both sides and not involve the economic or political domination of one sex by the other. Belief in sexual equality lies at the basis of gender awareness and provides the basis for collective participation in the process of women's development

(d) *Participation* This level of equality is concerned with women's equal participation in the decision-making process, this means participation in the processes of policy making, planning and administration It is a particularly important aspect of development projects, where participation means involvement in needs assessment, project formulation, implementation and evaluation Equality of participation means involving the women of the community affected by the decision taken and involving them in the same proportion in decision making as their proportion in the community at large

(e) *Control* This level entails not only the participation of women in the decision-making process, but utilisation of this participation, through conscientisation and mobilisation, to achieve equality of control over the factors of production and equality of control over the distribution of benefits Equality of control means a balance of control between men and women, so that neither side is put into a position of dominance or subordination. Till the early 1970s, Indian development planning continued to be governed by the unchallenging assumption, shared widely, that the household is a unit of congruent interests, among whom the benefits of available resources are shared equitably, irrespective of gender As a consequence, women's needs were presumed to be taken care of by development inputs The concept of the unitary household and the gender neutrality of development interventions based on it have been increasingly challenged during the last 25 years

"Towards Equality The Report of the Committee on the Status of Women in India (CSWI)" (GOI, 1974) highlighted that rather than improving women's status, the dynamics of 'development' had created new imbalances and disparities such as the declining sex-ratio, lower life expectancy, higher infant and maternal mortality, declining work participation, illiteracy and rising migration (GOI, 1988) The most significant outcome of the CSWI report was the recognition that "women as a group are adversely affected by the processes of economic transformation "

Shramshakti (GOI, 1988)—the Report of the National Commission on Self Employment and Women in the Informal Sector, set up by the Government of India—provided a focussed overview of the appalling conditions and exploitation of poor rural women struggling to support their households One of the significant findings was "that one-third of all households were solely supported by women and in another one-third, 50% of the earnings were contributed by women" (GOI, 1995). The poorer the family, the more it depends for its survival on the earnings of its female members (World Bank, 1991).

A participatory programme like watershed development concerning a sector in which women are major actors, needs to be particularly sensitive to gender disparities. It should address the constraints which prevent women from participating as equals Given poor rural women's negligible ownership of private resources, recognising and strengthening their customary rights to CPR of which they are major users, needs to be made an explicit objective. To ensure that women's specific needs and interests receive equal attention in a development initiative, their direct participation in decision-making is a prerequisite. However, even direct participation may only enable women to ensure that their existing day-to-day condition is not worsened further. The broader goal of promoting gender equality requires transformative strategies which facilitate long-term changes in gender relations based on more equal distribution of resources and responsibilities, as well as power and authority between women and men.

Issues of gender equality cut across broader issues of equity between the more powerful and marginalised sub-groups within communities. Although, the status of *adivasi* (tribal) women varies between regions and tribes, it is widely recognised that they enjoy a better status than women in the mainstream Indian society In the traditional forest-based *adivasi* economies, women's important role as gatherers of forest foods and subsistence goods from common pool forest resources made them economically valued members of the community This is reflected in the tradition of bride price instead of dowry among most *adivasi* communities (as seen in Jhabua). Despite the hard work they invest in cultivating private lands, all income from private lands is strictly considered the male landowner's income (Kelkar and Nathan, 1991) The degradation of the natural environment, particularly deforestation, has worsened the material condition and social status of *adivasi* women due to its drastic impact on traditional gender relations Three generations back, Bhil women had a clear set of rights, access to land and its produce, freedom of movement in forests and a valued status in the household. Today, in Jhabua district, male migration and abandonment of women is resulting in a preponderance of female headed households among the Bhils Abandonment of women due to the increasing practice of bigamy, even trigamy, by the men, leaves the pauperised and indebted women to fend for themselves Promoting women's equal participation in community institutions in such a context poses the challenge of changing cultural attitudes, norms and traditions which exclude women from such forums This requires developing focussed strategies for changing traditional attitudes and practices to create space for women in the local institutions in watershed

A women's development project may be counted as improving the status of women to the extent that the progress is seen in the following indicators

(i) *Basic needs* better provision for women of such basic needs as food, water, fuel, housing and health care, proportional distribution of basic needs between men and women

(ii) *Leadership roles* proportion of women to men in leadership roles in the community, involvement of women as women's leaders on women's issues

(iii) *Consciousness* awareness amongst women regarding women's needs and women's issues, awareness of discrimination against women, ability to analyse issues in terms of women's interests and women's rights

(iv) *Needs Assessment* involvement of women in identifying the priority needs of the community and in identifying the special needs of women.

(v) *Planning* involvement of women in project design, implementation and evaluation

(vi) *Sexual division of labour* involvement of women in tasks traditionally performed by men; level of involvement of men in tasks traditionally performed by women; number of hours per day worked by the average working woman in comparison to the number worked by the average working man.

(vii) *Control over the factors of production* women's access to, and control over land, credit, distribution of income and accumulation of capital

The order in which these indicators are presented is neither intended to imply an order of priority, nor a sequence of what should come first and what should come later. It is merely suggested that a successful project should be making progress across several of these indicators, and that a successful programme should include projects which seek to improve women's status across the full range of these indicators

Gender dimension in watershed programme

Planning for watershed programme is often shaped by a primary focus on the output of the plan at the expense of the process through which the plan is prepared and designed A comprehensive and realistic WDP can be prepared depending upon the learning capacity of the agency, how well it copes with mistakes and contingencies, how it uses its experience to strengthen institutional capacity and to what extent it shares the knowledge gained with the community The manner and approach with which PIA works with the community at planning stage is crucial The adopted strategy must be based on adequate knowledge, understanding and communication with the community and women will play a vital role in this process A productive and sustainable relationship between a PIA and a community will decide about the process of change The entry strategy adopted should have following stages

1 Consensus with the community on the values, goals and objectives for watershed interventions
2 Negotiating an agreement on what the community and the PIA have to offer to each other, how the participation strategy should be organised and what will be the role of PIA and the community in achieving the jointly planned outcomes
3. Arriving at a common analysis of the situation so that not just the problems and needs are identified but the reasons are also jointly understood

Implicit and inbuilt in this approach is the establishment of a partnership in which the PIA listens, learns and consults Developing an informed perspective on the links women have to wider environmental, political and socio-economic systems, implies the agency's willingness and capacity to appraise women's practical and strategic interests The identification of such interests must be a process which is sensitive to the community and based on the community's capacity to work and perform Extent to which women have access to local institutions and whether these institutions can be used to meet particular practical and strategic needs should be assessed The PIA may learn to formulate informed judgement and accurate assessment based on following approaches

(i) improve understanding of how gender relations work within the community,
(ii) improve its ways of interacting with the community, and
(iii) improve the quality of information used for planning purposes.

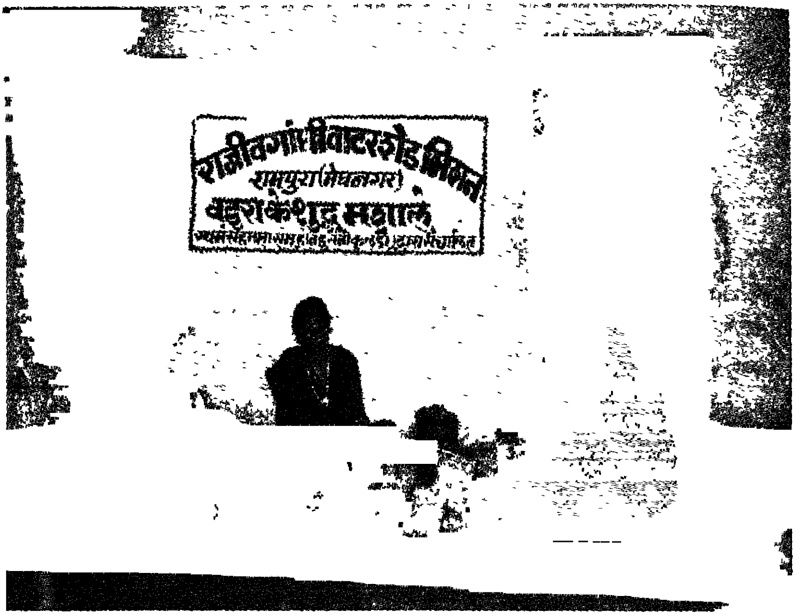
The relative access to and control over resources and benefits include an awareness of the differential access to power which is integral to the division of labour by gender. An increased and accurate understanding of gender relations with a household structure may be adopted. It is a misconception that household is homogeneous decision-making unit In all rural societies different members have separate productive and entrepreneurial roles and there are competing, unequal and often conflicting claims on resources and output for the satisfaction of basic needs. A key principle in understanding gender relations in a household is to consult both men and women and document their different activities, resources and responsibilities Indicators of how women and men experience changes to their environment, seasonality, access to preferred technologies, large family size, use of liquor, increasing costs of inputs for production, PIAs style of intervention may increase qualitative information about women's activities, the resource they command and the responsibilities they manage. The findings and informations gathered in the household should necessarily be tested for their impact outside the household (see Plates 59, 60, 61 and 62)

Women are not homogeneous social group and their needs differ according to their relative age, caste, religion, class, activities, resources and responsibilities. A need assessment should take into account this social and personal heterogeneity It is important that the context and style of discussion should be accessible to women for whom speaking out

Plate 59 *Educating the girl child*

Plate 60 *Promoting awareness about health, hygiene and sanitation among women*

Plate 62 *Economic independence through rural industries*



may be an unfamiliar event—the location, materials used, the size, membership of the group. Providing women with enabling skills for group management or supporting existing institutions that women use may be a vital investment in the development process, even before the entry stage is agreed. As Mosler and Levey say, consultation on issues that perpetuate gender inequality and the active participation of women in the planning process is desirable, not only as a means of achieving development objectives, but as an end in itself. The linking of short-term practical needs to long-term strategic needs must be decided by frequent consultation and monitoring with the women concerned and testing solution within the community In order to ensure that women are an integral part of the process, it is important to improve gender awareness among all the participants, to find ways of communicating with the women directly and to basic planning on the best level of information possible.

A set of questions is given in Chart 21.1. They are key questions for the four stages in the project identification, design, implementation and evaluation.

Gender and natural resource management

The ways in which women traditionally use natural resources are becoming increasingly unviable. There are four main reasons for this, each of which has a cumulative, negative impact on the lifestyle of rural women.

1 In many areas, traditionally useful multipurpose tree species are becoming increasingly scarce as desertification and deforestation take their toll. Women, therefore, have to undertake longer walk to collect fuelwood and other forest products, and this adds further hours to their already stretched working hours

Chart 21.1 *Women's dimensions in project identification, design, implementation and evaluation*

(I) In project identification:

(a) Assessing women's needs

1 What needs and opportunities exist for increasing women's productivity and/ production?

2 What needs and opportunities exist for increasing women's access to and control of natural resources like water, fuelwood, CPR, etc ?

3 What needs and opportunities exist for increasing women's access to and control of benefits from CPRs?

4 How do these needs and opportunities relate to the programme's other general and sectoral development needs and opportunities?

5 Have women been directly consulted in identifying such needs and opportunities?

(b) Defining general project objective

1 Are project objectives explicitly related to women's needs?

2 Do these objectives adequately reflect women s needs?

3 Have women participated in setting those objectives?

4 Have there been any earlier efforts?

5 How has the present proposal built on earlier activity?

(c) Identifying possible negative effects

1 Might the project reduce women's access to or control over resources and benefits?

2 Might it adversely affect women's situation in some other ways?

3 What will be the effects on women in the short and long term?

(II) In project design and implementation:

(a) Project impact on women's activities

1 Which of these activities (production, reproduction, maintenance, socio-political) does the project affects?

2 Is the planned component consistent with the current gender denomination for the activity?

3 If it is planned to change the women's performance of that activity (i e , focus of activity, remunerative mode, technology mode) is this feasible and what positive or negative effects would there be on women?

4 If it does not change it,is this a missed opportunity for women's roles in the development process?

5 How can the project design be adjusted to increase the above mentioned positive effects and reduce or eliminate the negative ones?

(b) Project impact on women's access and control

1 How will each of the project components affect women's access to and control of the resources and benefits engaged in and stemming out from the production of goods and services?

2 How will each of the project components affect women's access to and control of the resources and benefits engaged in and stemming out from the reproduction and maintenance of the human resource?

3 How will each of the project components affect women's access to and control of the resources and benefits engaged in and stemming out from the socio-political functions?

4 What forces have been set into motion to induce further exploration of constraints and possible improvements?

5 How can the project design be adjusted to increase women's access to and control of resources and benefits?

Contd

Chart 21.1 *Contd*

(c) Women's dimension in project formulation

1 Are project personnel sufficiently aware of and sympathetic towards women's needs?
2. Are women used to deliver the goods or services to women beneficiaries?
3 Do personnel have the necessary skills to provide any special inputs required by women?
4. What training techniques will be used to develop delivery system?
5 Are there appropriate opportunities for women to participate in project management positions?

(d) Organisational structures

1 Does the organisational form enhance women's access to resources?
2 Do the organisations have adequate power to obtain resources needed by women from other organisations?
3 Does the organisation have the institutional capability to support and project women during the change process?

(e) Operations and logistics

1 Are the organisation's delivery channels accessible to women in terms of personnel, location and timing?
2 Do control procedures exist to ensure dependable delivery of the goods and services?
3 Are there mechanisms to ensure that the project resources or benefits are not usurped by males?

(f) Finances

1 Do funding mechanism exist to ensure programme continuity?
2 Are funding level adequate for proposed tasks? Is it possible to club funds available under other women welfare and development programmes?
3 Is preferential access to resources by male avoided?
4 Is it possible to trace funds for women from allocation to delivery with a fair degree of accuracy?

(g) Flexibility

1 Does the project has a management information system which will allow it to detect the effects of the operation on women?
2 Is there enough flexibility in organisation to adapt its structures and operations to meet the changing or new-found condition of women?

(III) In project evaluation:

1 Does the project's monitoring and evaluation system explicitly measure the project's effects on women?
2 Does it also collect data to update the activity analysis and the women's access and control analysis?
3 Are women involved in designating the data requirements?

(a) Data collection and analysis

1 Are the data collected with sufficient frequency so that necessary project adjustments could be made during the project?
2 Are the data fed back to project personnel and beneficiaries in an understandable form and on a timely basis to allow project adjustments?
3 Are women involved in the collection and interpretation of data?
4 Are data analysed so as to provide guidance to the design of other projects?
5 Are key areas for indepth analysis, research and focus identified?

2. As more and more men find employment in the towns and cities, women are forced to carry out jobs previously done by men This leaves little time for the lengthy business of collecting and processing natural products, however important they may be to the family economy.
3. New technologies are changing land use, reducing the availability of minor forest products that women have traditionally used as a source of additional income. These technologies are frequently introduced without providing women with other income-earning alternatives.
4 Development projects often improve conditions for the men, leaving women with as much, or even more to do than before.

These four factors need to be considered by planners if they are to help restore the balance between women's needs and the natural resources available to them. Each includes issues related to both poverty and gender Productivity and efficiency, distribution and equity and conservation and environmental quality are the main goals of natural resource management Productive activities for the household are crucially affected by decrease in natural resource availability Social, economic and environmental costs of fuelwood scarcity to women and their families can easily be adjudged from time allocation/daily schedule technique The capability of land to support grazing and fodder production for household livestock has declined, burdening women to support the livestock Access to and control over water for household use creates new problems for the women in the household Loss of forest habitat that supplies supplementary food, fibres, medicines and other goods has adversely affected household maintenance and small scale rural and household industries The least powerful groups of society suffer first from loss of access to natural resources-like women with their primary responsibilities for household maintenance and wide ranging productive work, forest dwelling people dependent on forest habitat for sustenance and trade goods, landless people dependent on wage labour and CPR for their livelihood The effects of management of natural resources also reach to the powerful groups Programmatic attempts like JFM and integrated watershed development programme, to integrate women into active responsibility for natural resource management is a new phenomena. The women in watershed areas require increased awareness of gender differences and disparities, new sets of social and technical skills and a decided revision of the traditional outlook. Women are always an important participant group in watershed programmes and in natural resource management There are many hindrances and obstacles for their effective role play in watershed development

1 Lack of access to technical education and training, credit extension information, material inputs, markets and funding
2 Lack of ownership and tenure rights to natural resources
3 Inequitable distribution of goods and services supplied from natural resources
4 Difference of perception between women and men, PIA and community about types and allocations of resources
5. Lack of inputs into planning and decision-making process

According to Ruth Dixon, watershed projects designed specifically and exclusively to benefit women appear justified

— where there are strong taboos in the community against unrelated males and females working together,

- where the effects of past discrimination need to be overcome;
- where most households are headed by women;
- where women specialise in tasks such as bamboo-crafts etc., that could be made more productive with outside help; and
- where women request a measure of self-reliance to avoid conflict or competition with men.

These circumstances may not exist in the watershed areas. The important factors that mitigate against women participating fully in watershed projects can be easily summarised Women are short of land, time and money, they are often poorly organised, have restricted access to political power and a limited ability to influence decision-makers, they are more often illiterate than men and have no collateral to offer for credit; and they are restricted in the jobs they are allowed to do and the distances they are allowed to travel. Some of the factors that prevent women from participating in projects are similar to those that exclude men. One of the key issues is land tenure. Because trees grow slowly, few farmers are prepared to plant trees unless they are sure they will enjoy the benefits. They need secure tenure to land and trees. If this is often a problem for men, it is nearly always so for women A prevalent, but mistaken, attitude has been that if you give to the men, you give to the women Women without legal rights to land have no collateral to offer for loans to buy equipment, seeds or fertiliser—all of which they need Women who have no rights to use certain trees—as is common in many societies—have no incentive to plant them. And women who are forbidden by custom to plant trees have little chance to participate in forestry projects, even those that could provide them with substantial benefits.

If women are to participate in watershed projects they must also have the time. They rarely do. In fact, the more women might benefit from such a project, the less they are likely to have the time to do so. For example, collection of fodder has become immensely time consuming for women in villages but it has sometimes proved hard to persuade them to plant fodder trees. The main reason turns out to be that the women are often too busy collecting fodder to spare the time Lack of mobility is another drawback In many societies, women do not enjoy the same freedom to travel as men, or are not allowed to work away from home. Often women are anxious to lift these outdated restrictions Experience also shows that traditions of this kind often reflect idealized behaviour rather than what people really do Poorer women, in any case, have learned to put survival above theoretical restrictions about the roles they should play in society. In some cases, simple commonsense can resolve the issue. In Jhabua, the constraint of mobility was overcome by moving nurseries into the women's compounds A solution to problems of communication between male project staff and women's groups can be resolved by ensuring that women staff are hired for the project While not all constraints to women's participation are as easily resolved, policy measures can go a long way to help

Special care is, therefore, needed to ensure that women who help plan and execute projects play sustained roles in implementation and receive due benefits from them One of the most important ways of doing this is to design projects that provide benefits for both men and women The precarious balance between women and natural resources should be restored It is obvious that the participation of women in CPR management is crucial for the success of watershed programme Following are suggested steps to restore the balance between women and CPR/natural resource management in watershed areas

1 Explore gender issues through two-way communication with rural women, recognising that the needs of men and women not be the same and that the impact of projects on them may therefore be different.
2. Investigate the customs, taboos and constraints that women face, realising that knowledge and commonsense can go a long way in overcoming these constraints.
3. Promote the role that women do and can play in CPR management at each level and analyse the ways in which projects either include or exclude them
4. Exchange information with individuals at every level with local women on CPR and its management and with PIAs on involving women in CPR management
5. Support women's groups and encourage the formation of new ones that help women gain access to decision-making and the political process and strengthen women's support for one another
6 Work together to provide access to natural resources by recognising, customary and traditional women's holdings and seeking creative solution for landless women
7 Collaborate to make credit and income available to women, either individually or through women's groups.
8 Consult with women before introducing new technologies, ensuring that women needs have been considered, and the impact of new techniques on women's lives have been evaluated

Chart 21.2 *Checklist for watershed development projects, if integration of women in development is an objective*

(a) Project objective

1 What are the objectives of the project?
2 Are women specifically mentioned as either agents or beneficiaries?
3 What, if any, are stated benefits for women (e g , acquisition of skills, increased productivity, opportunity to earn cash income, etc)?
4 What assumptions are made in believing that project inputs will lead to these benefits?
5 If women are not specifically mentioned as participants, would their actions be relevant to the objectives of the project?

(b) Availability of basic information

1 What socio-economic information is already available which is relevant to the target group in general and women in particular?
2 Is information on economic arrangements at household level, including role of women, adequate for purposes of project (structure and size of household and developmental cycle, division by sex/age of labour, decision-making rights over land, control over saleable products, sources of cash incomes, off-farm activities, seasonality of labour demands)?
3 If more information is essential, what arrangements are being made to obtain?
4 If consultants are assisting with feasibility studies, have they been briefed to consider situation and contribution of women as appropriate?

(c) Project design and preparation

1 Has there been consultation with people whose lives will be affected by the project and what attention has been given to women in this?
2 Are women involved at any level in the professional planning and implementation of this project?
3 Are women to be given access to the new opportunities and services which the project provides (viz , local training, agricultural extension, new allocation of land rights, credit

Contd

Chart 21.2 *Contd*

arrangements' membership of cooperative, and employment during operational phase)?
4 If not, what are the reasons?
5 Are resources adequate to provide these services for women? Are women extension staff available in sufficient numbers?
6 If project is likely to have adverse effects for women (see below) what actions are planned to counter balance this?

(d) Anticipated impact

1. How will project affect women's access to economic assets and cash incomes (access to land, opportunity for paid employment or other income-earning activity, assistance with economic activities from other members of household, control over sale of product) Are there gains expected other than those stated in objectives (see above)?
2 How will project affect women's allocation of time?Will their work load increase/decrease as a result of innovation or changes (mechanisation, new agricultural inputs and cropping patterns, withdrawals of labour by other household members, agricultural advice, nutritional or health teaching, changes in distance to farms, workplaces, water supply, firewood supply) If workload is decreased, does this involve loss of income for women?
3 How will project affect subsistence within the target group and women's control over food supplies for household? Will promotion of commercial agriculture affected availability of land for food, grown mainly for family use, women's access to land, labour inputs (male and female) on food crops?.
4 Will any sources of food be removed or decreased?
5 Will women be increasingly dependent on partner's cash income for household food and necessities? If so, will this income be sufficient to make good subsistence losses? Can it be assumed that male income will 'trickle down' sufficient to meet basic household needs?
6 Will there be a change in staple diet? Will this be acceptable? Will it involve increased time in preparation?
7 Will changes in labour allocation alter nutritional needs of any member of household? Are subsistence resources or increased cash income sufficient to meet them? If not, what are probable consequences for women and children, especially if unequal food distribution patterns are customary?
8 Is the project likely to have any adverse consequences for women within groups and categories not immediately affected?

(e) Evaluation

1 Is provision being made to monitor and evaluate the impact of the project on women?
2 Will available baseline data be adequate for this purpose?
3 What factual indicators would be relevant?

Empowerment of women by forming groups

Role of credit groups in empowering women

Empowerment of women can be ascertained by credit group formation

(1) Provision of inputs to an individual family is not sufficient to raise the family above the poverty-line and to keep it there The support required is part of the backward and forward linkages as well as the basis of the environment of social security and mutual assistance which the poor family requires in order to take risks. The groups effectively meet these requirements.

(2) Provision of inputs directly to individual often results in a higher opportunity cost In

other words, the cost of materialising the new input is often higher than the cost incurred previously. The group, on the other hand, creates an environment in which the family will not ask for resources that cannot be maintained because the other members will refuse the credit knowing fully well that it is not viable.

(3) Provision of inputs directly creates a relationship of debtor-creditor between the PIA and the individual. This is an unhealthy relationship and undermines all efforts for community organisation and motivation. The lending operation of group does not create a debtor-creditor relationship Being a member of the group a loanee is simultaneously a debtor and a creditor He/she hence feels responsible to repay on time. The group being right at his doorstep, a loanee can return funds without incurring costs The group can and does apply pressure on the few members who do not repay promptly.

(4) Some needs of the poor cannot be met by giving inputs for the economic development of individual families; e.g , drinking water, access to health services, roads and transport, etc. Some of these assets have to necessarily be managed collectively by all the people in the village. The smaller groups in each village come together to lobby for and manage assets and services.

(5) Educating each and every individual family is neither possible nor sufficient to bring appropriate changes in the values and attitudes of the family For example, changes in attitudes towards women, scheduled castes, other religious groups, etc The social values of families largely shaped by the values of the people with whom they live and interact Hence, it is imperative that we work collectively if we want to bring about changes in the values and attitudes of individual families

(6) Groups foster the emergence of innovative, appropriate and replicable ideas by providing the people opportunities to come together, share and learn from each other's experiences This is not possible in an individual approach

(7) Groups throw up new leader in the village. These emerging leaders who have the support of the group are chiefly from the economically weaker sections, unlike the traditional leaders who belong to the upper caste and class. This is reflected in the fact that the villagers look up to the group rather than traditional leaders to help them solve their problems

(8) The group approach has brought to the surface and made operative latent traditional values like group support, thrift, group action These values existed when society was bound by caste With time, these values become dormant and latent Once a group begins to function which are formed on the basis of social functionality, these latent values are activated This is proved by several decisions taken by the groups which affect their behaviour patterns

Group formation

Group formation is a dynamic process, some conscious efforts (especially from WDC) also have to be made for forming and developing a group. The initiative from at least one woman to try to face a specific problem becomes a starting point of group formation The formation of a group can also be initiated or stimulated by PIA The motivation of the first woman, local or outsider, significantly influences the stability, continuity and growth of a group When the need to be organised is felt and recognised by all members, a strong group is formed. The more similar the background of the organiser to that of women members, the greater the possibility of having a cohesive and durable group. An effective organiser must keep in mind that:

- each woman in the group is equally important,
- those who hesitate or do not want to join the group might have logical reasons which have to be understood,
- she should organise women in 'their' own interests,
- she should know how to communicate effectively,
- group members should learn to relate to each other as group members,
- it takes time for women to make up their minds to join the group, they have to be repeatedly approached, and
- she should establish her credibility and gain their confidence by helping them with their difficulties, whenever possible.

The organiser may have to function as motivator, friend, educator, learner, informer, facilitator, interpreter, confronter, trainer, etc.

Steps in formation of credit groups

Following are the seven steps in formation of credit groups:

Step (1) The new groups of women learn from the PIAs about the function of a group, the manner and procedure of meetings, method of saving, the process of obtaining the loans, the way to choose their leader and other group activities. These processes further strengthen their group assistance from extension workers.

Step (2) The new groups of women supported by the WDC and PIA go on to select the leaders, bring their saving, and learn how to keep records of various aspects They meet weekly with guidance and support of WDC/PIA

Step (3) Impressing on the new group members that their group is a partner in a systematic, well-planned and disciplined programme. The attention must be drawn to the following points-those attending group meetings or sessions should consist of poor women, they should be from neighbourhood families (one each from every family) and money transactions should be trusted only after enough confidence building is ensured For the leadership of the group, it is better not to select·

- those involved in money lending,
- those involved in active dirty politics, and
- office bearers in community development programmes.

The group should focus on savings and credits, meetings, collective strength, collective responsibility, discipline and accounts management.

Step (4) At this step, the group may be given a package of stationery which includes two ball point pens, register for documenting minutes and accounts keeping, footroller, etc The register are used to record (1) minutes of the weekly meetings, (2) weekly savings, additional savings, (3) loans given, and (4) re-payments/recoveries Separate registers may be used for these different functions Intensive capacity-building excercises for record keeping of minutes of the weekly meetings, compulsory/voluntary savings, urgent and other loans, attendance and participation etc should be undertaken

Step (5) At this stage, a printed paper with elaborate rules and regulations should be distributed by the PIA These rules and regulations should be thoroughly explained to every member. The group after management for six months should apply to the district women and child development officer (DWCDO) for funds under DWCRA scheme The application must be accompanied by regular meeting's minutes register, bank passbook, accounts registers showing regular savings and thrifting for atleast six months The DWCDO after examining the case on merits, release Rs 25,200 under DWCRA scheme in the group account

Step (6) A similar application may be forwarded to the PIA for SHG revolving fund Under the national guidelines, Rs. 50,000 from group mobilisation head may be provided to the women credit and thrift groups working in the watershed by the PIA

Step (7). Another application should be forwarded to a nationalised bank for SHG loan. The bank provides for four times money collected by the SHG over last six months as soft loan

Different models have emerged in terms of thrift and credit groups. Often, the focal point of PIA is to organise women into groups which could be called thrift groups The groups are encouraged to save on a daily, weekly or monthly basis Small amounts so generated lead to a process of generating savings from within the group. This, in turn, facilitates lending by the group and encourages it to build on the funds Alternatively, the PIA creates a small revolving fund from which the members borrow and repay In between the two models, the funds from the PIA and the funds generated by the women groups are shared in various proportions as the capital or principal Similarly, the purpose of utilisation varies from simple consumption needs to the production needs of economic activities or for agricultural purposes There are number of other aspects which are interwined in the process The groups develop their own management systems and accountability for handling their money, the group develops its own norms, procedures and rules in terms of dealing with their affairs, the groups also deposit the funds in the formal banking system and learn to borrow through the bank which previously they might never have had access to From the group, local leadership is developed to handle its own affairs The interaction among the small group of women does not restrict itself only to the affairs of the money transactions Generally, their problems as women and their issues within their groups and villages and even their personal problems are shared Thus, thrift and credit contributes as a support programme to the empowerment process of the local women From these varied experiences we could identify how the voluntary agencies or PIA's have found a way through which an alternative credit support system is developed for the poor women, so that they could be emancipated from the unjust money lenders and the vested interest groups who, by offering small loans, keep the landless poor in the bondage Therefore this programme often provides an alternative system on which the group could rely besides being accountable for their own money and developing their self-confidence to handle large amounts of their funds and also build up their morale and leadership to act on larger issues

These groups assist in improving the socio-economic condition of the poor, organising them into self-help groups and empowering them to tackle the issues relating to their own life Rural credit groups have increasingly come to the attention of NGOs and PIAs working with rural poverty and are seen as an effective means to tackle economic problems of the rural poor in watershed areas

What are credit groups

What is in plenty, to meet the needs of a 'rainy day' is a common and natural instinct. This instinct to save in times of bounty for use later is present in human beings as well. But to be able to save, one needs to have an income level that is adequate to meet expenses and have something to put aside. Thus, saving is dependent on income levels and expenditure patterns.

It is felt that the rural poor, despite their low wages, can put aside some amount for later use. This is possible because there are seasons or periods when incomes are sufficient (even if small) to save small amounts. Besides, there are unnecessary expenditures that can be reduced to be able to save a small amount Thus, the credit groups are efforts at getting the rural poor to put away small amounts of money for later use

Credit groups: How they function

In most credit groups, the small saving and credit is an activity. The goals of the group may also include literacy, collective action to solve common problems, make representation to authorities, to share experience etc. And savings is one major element of the activities of the group. The body meets at regular intervals. The credit activity is usually tied to this meeting, where the members' contribute their savings. Most groups keep a record of the amounts saved by each individual either in a book or specially printed passbook At the same meeting, they also decide to sanction a loan of someone who wants to borrow, to meet a need that has arisen. The amount that is borrowed and whether any interest is to be charged is decided by the group, as also the terms of repayment. Depending on the amount available, the group may lend to more than one borrower. This collection and lending procedure goes on at each meeting and repayments and balance in favour of a member or loan due to a member is kept track of in the meetings

It is recommended that the management should be fully handled by the groups and its elected members. The project staff may be involved in a purely facilitating role or in the role of collecting, recording and keeping the collection in *Vikas Mandir* or a bank, as well as in decision-making on lending etc

An examination of the utilisation of the borrowings from credit groups show an interesting pattern·

In the beginning, the members borrow to meet their consumption needs, especially in the season when employment is scarce. Later, the borrowings are used to settle loans taken from other sources like moneylender or the banks Only at a later stage is the borrowing used for productive purposes such as purchasing economic assets, meeting expenses for buying farm inputs, raw materials for home-based productive activities etc In some groups, the funds are also utilised to meet expenses of making a petition to panchayat or government authority for providing services like water, roads, getting a *patta*, etc

It may be argued that these credit needs are to be met by the various formal and informal credit institutions that are operating in the rural set up. In fact, regional rural banks were set up precisely to meet these needs and most commercial banks have branches in rural areas to meet the banking needs of the rural economy. Apart from the formal institutions, the money lender has been a part of the credit scene for centuries The relationship between the rural poor and the money lender spans several generations of 'interdependence' with its own dynamics. This cannot be ignored while studying the rural credit set up

There are some very valid reasons for the members to prefer credit groups as sources of credit over the other formal and informal institutions In the formal institutions, the procedural requirements are so complex, that the semi-literate and illiterate rural poor get intimidated and discouraged from approaching these institutions. Also, banks are not in a position to service loans of a small denomination For example, it would be futile to expect that a poor farmer get a loan of Rs. 50 on a weekend to take his sick cow for treatment Moneylenders, on the other hand, are flexible in their lending and are readily available. But they demand some security, charge exorbitant rates of interest and are ruthless in repayment conditions Once a poor family gets into the clutches of the moneylender, rarely can they ever get out of them

Thus, the only viable source of credit for the rural poor seems to be their own credit groups Credit groups are also a means of teaching the rural poor how to manage finances They may not have the necessary literacy and numeracy, but are rich in their native wisdom in dealing with resources. This can be seen in the way they deal with every paise of expenditure, income, interest due and repayment terms and utilisation of the savings of the credit groups.

Some of the most common purposes for which loans are advanced are as follows

— *Agricultural credit* The advantage of approaching the group for credit is that there is no paper work involved, credit will be available on time and members can negotiate the amounts they require instead of accepting a pre-determined package

— *Social occasions such as marriages and funerals* The above two are the most common causes for people becoming indebted to moneylenders

— *Sickness and accidents* requiring emergency relief

— *Short-term credit for small business purposes* Left to themselves and free of feasibility studies, many rural people are quick to spot a business opportunity that they feel they can take advantage of Often, loans (working capital) are required for quick-return business ventures (e g , trading in seasonal flowers and fruits) that can be paid back within the space of a few weeks If this money is not available, it is a good opportunity lost

— *Small loans to be invested in income-generating programmes* While a farmer may be eligible for a loan package that can buy him 20 sheep, what he may want and can manage is only two sheep A credit group understands such priorities much better than a bank can

— *Credit for educational and travel purposes* Though not a very high-priority need, some families have ambitions that can be met through the credit group

The sense of ownership can be created only if the group members have a control over the funds, are involved in decisions on their utilisation and their use for things of interest

Where the credit has been linked with on-going economic activities, like dairying, sheep rearing, silk reeling, coir rope making, etc , the management of funds is much more seriously taken Similarly, if the group is working towards setting up a new economic activity that will need investments, such as a fair price-shop, a tailoring centre, or a petty business, the credit group activity is more meaningful

Another important issue is interest paid on savings and charged on borrowings, if these are not comparable to that of other institutions, then it cannot be viable The basis of this has to be clearly explained to the members. For example, in one women's credit group, the members asked why they had to pay any interest when they were drawing money from their own savings. That this interest would go back to their own savings had not been clearly explained to them. In another group, the members expressed their willingness to pay interest rates that are somewhat higher than the bank rates, but much lower than a moneylender's rate. The need here is to make the members aware of the concept of cost of money. For credit groups to be seen as fair sources of funds, issues like the conditions for borrowing and terms of repayment have to be examined too if these are seen as group activity. If the group is ridden with conflicts and contradictions, power struggles and domination by interest groups, the credit activity too will be complicated with these factors. If the group has reached a certain level of maturity, trust and cohesiveness, then the demands of managing credit can be tackled by the group effectively.

Step 1 Identification and preparation of small groups

(a) Potential groups are identified through 'village entry' PRAs and entry activities (this needs to be understood that groups may already exist in the village before the entry of PIA. Identification of those natural groups and their intra and interrelationship should be the main focus).

(b) Groups will be small (size 15-25, may be sub-groups of only 8-10), socially and economically homogeneous, close in residential and kinship terms, groups should not include patronage relations (it is not necessary that all the potential members of an identified natural group should start together at a point of time).

(c) Group members represent their whole households But each household is only represented in one group. If under the same group, women want to maintain separate savings and want to meet separately to address their needs, this must be encouraged

(d) Initial training on purpose of group discussion on the importance of saving; the nature of poverty, debt/high interest rates; the need for consumption credit, the importance of savings, and the advantages of a group and of control of money remaining within it should be encouraged

(e) Women select to join a group. In each (new) village a beginning is made with one strong group first, then others will follow All groups may not be identified at the same time in a village. Begin with one group who feel they can work together A group does not come into existence until its members have consciously decided that they want to come together other than in order to acquire project benefits (i.e , on a self-help basis)

Step 2 Beginning a group (0-3 months)

(a) A group meets regularly (weekly) on a fixed date and finds a suitable place/time and follow the suggested agenda.

(b) Over a few meetings the group agrees about its purpose, norms/rules for its functioning (community organisers assist in evolving norms) All discussions and agreements are minuted The purpose and norms/ rules may be written on a big sheet of paper and that may be explained in the group meeting

(c) The group selects its representatives and also one or more group *jankars* who facilitate meetings, collect savings, keep records, etc The leadership role of 'representatives' is not the same as that of *jankar*. There may be one specialist accounts *jankar*. As a rule group jankars are not paid by the project on salary basis Alternatively watershed volunteers may be involved in this process Leadership roles should rotate (changing each year). The successor leader should be selected in advance to allow for a programme of training for her (it is presumed that the person is already an active member of the group)

(d) Project staff (community organisers) become clear about their facilitating role, ensuring that they identify and help to meet training needs

(e) Regular savings begin This is more important than admission fees. Every member should also have a membership fee when the person is enrolled as a member There should be universal membership fee for all group members. The membership fee is not returnable and is the capital fund of the group. The saving amount is agreed by the group members (say Rs 5 per week). Savings are pooled into a common fund, but can be withdrawn by a member. This is not encouraged (norms need to be agreed for withdrawal) The withdrawal should not exceed the amount saved by individual member

(f) Savings from wages on project activities (e g , SWC) may be a source of savings, but it must not be the only or first such source. The group must have begun its voluntary savings by the time such programmes are initiated A group should be formed and functioning before programme related savings begin

(g) Individual passbooks should be issued to members Also when the passbooks are maintained they should be filled every time in the meeting All books of accounts and passbooks need to be kept with group *jankar* (in a metallic trunk) They need to be regularly shared with members who can have individual passbooks (as desired)

(h) A bank account for savings is opened on group-basis The signatories are the agreed representative of the group PIAs should not become signatories and should not handle villagers money

(i) The group agrees the basic records to be maintained (attendance register, minutes book, savings register, loan ledger) Secretary (WDC) and community organisers should advise and help in getting appropriate basic records set-up Secretary (WDC)/ community organisers are directly involved in record-keeping for not more than nine months, can be extended to 12 months Where necessary, group member select and employ a literate book-keeper and fix a rate per meeting (or as the case may be). But later, members should begin to document all transactions of the group themselves.

(j) The groups begin to follow a systematic training syllabus as per the details the secretary (WDC)/community organiser need to facilitate in meetings

(k) Literacy/numeracy classes begin and include elements of development education These are conducted by a trained volunteer (the duration and frequency of classes in a week can be decided by the group Classes, may be conducted in night or on every alternate day)

(l) Project facilitates development education inputs, exposure visits and follow-up reflection, provides information (e g , on government programmes, legal issues, etc)

(m) Groups remain informal, they are not registered as 'societies'

(n) PRA techniques are done in groups, especially in regular weekly meetings and as part of group training/awareness building These include issue-focussed PRAs dealing with credit needs, matrix ranking credit source, flow diagrams, pie charts, seasonality, etc.

Criteria of achievement (after a minimum of 3 months)

Regular meetings.

100% attendance.

Regular savings

Accumulated savings in say three months (about Rs. 60 person, common fund of Rs. 1800-2000)

Agreed and enforced rules/penalties for group-for non-attendance etc.

Identified/trained representatives and group *jankars*

All transactions supported with documentation (attendance registers, minutes books, books of accounts).

When a group has achieved these things it can begin credit management, that is lending from its common fund.

Step 3 Credit management (loans from own savings) (3-9 months)

(a) Group itself agrees rules for credit, interest(at least enough to cover group expenses and contribute to the public fund), repayment, eligibility, amount/purpose of loan, etc

(b) Small loans are lent and recovered from the common savings fund Loans will be small (even Rs 25-30) lent to members to meet immediate needs.

(c) The group learns about need-based lending and how to manage a scarce resource to prioritise, to reject as well as agree loans to meet a few needs at a time.

(d) The group continues to build the common fund through interest payments, donations, imposed fines, income-generating activities (e.g., pump hire) etc.

(e) Further training is provided for group members in book-keeping etc

(f) The group takes up some common activity (on small scale) related to needs

(g) At this stage, larger loans for inputs (seeds,fertilisers) should not be advanced.

Criteria for achievement (after 6-12 months)

Three or preferably at least six months successful credit management using saving alone.

Evidence (i e , based on a reasoning, understood and accepted by all members, i e., need-based lending).

The rejection of applications for valid reasons, e g , the group asks questions about the skills and resources of a person requesting a loan for goat what do you know about goat-rearing? where will you keep the animals? Loans are not given while overdue instalments exist, or to those who do not follow group rules

There are reasonable interest rates and repayment schedules based on purpose, risk, productivity etc

100% recoveries

All books and records are properly maintained by members or by a person appointed by them (but not exclusively by community organisers)

At least one community action programme has been implemented (some action of common group benefit)

When (and only when) these criteria are satisfied, will the project make a contribution or extend credit to the group The evaluation of the group against these criteria will be done by staff from other clusters in 'exchange evaluations'.

Step 4 Project contributes to the group-managed common fund (6-12 months)

Where the group has demonstrated management skills, the project makes capital contributions to the common fund to increase the capital available for the group, making it able to meet more of the members' credit needs The amount of such 'seed' money would initially be small and based on the savings already mobilised (upto 1 5 matching contributions) These are grants to the group, repayable to the group fund. They are given for any pre-defined purpose. Villagers continue to develop skills in credit management-selecting loanees, judging the validity of purposes etc.

DWCRA (Rs 25,200 revolving fund for credit and thrift groups), SHG revolving fund in watershed (Rs 50,000 for groups in a micro-watershed) or SHG scheme of NABARD/RBI (four times loan is forwarded to the group against amount saved by them for productive purposes) may be used as seed money.

Criteria for achievement

As for step 3 above, but further advanced
Regular meetings/ savings, rotating leadership
Equitable access to loans, good fund rotation
Group has sizeable working capital (Rs 2000 per member)
50% of members have acquired a resource, skill, asset for regular income
Completed training syllabus
Completed course of NFE/literacy/numeracy classes-all members can easily read their passbooks
Minimum one group has successfully started income-generating activity
Implemented community action programme or taken up public interest issues

Step 5 Group mobilisation (after 9-12 months)

(a) Once a group is effectively managing a fund of about Rs 30,000-50,000, then the group would ensure how revolving of funds would mature.

(b) The amounts are initially related to the amount of saving in the common fund. PIA should not come forward to meet 100% of demand (e g , for crop loans) The group negotiates an advance against its existing savings and money raised for the particular purpose (e g , crop loan) Grant contribution should be based on the performance of the group, the effective use of seed money provided (in step 4) the extent of savings, funds raised by the group etc The quantum of credit (e g , for input supply) is determined by the level of management competence of the group and not simply by demand

(c) These are grants by PIA to groups, but the advances by group to its individual members are strictly loans, strict repayment and recovery are to be ensured.

(d) PIA continues to provide training for group members, reducing community organisers time with the groups

At this stage community organiser visits become less frequent-at most attendance of one meeting every 4-6 weeks Group auditing continues Further training for volunteers is given PIA provides no more financial contributions to the group Instead links to banks are encouraged, as said earlier after two years of faultless working

A total of 1053 *Baira-ni-Kuldis* or credit groups in Jhabua have been operational since 1994-95 and have showed a path of ensuring empowerment of women groups in watershed areas. They have saved Rs 2.48 crores, providing them enough money for credit and thrift. More than 200 such groups have raised four times loans on their savings from SHG scheme of banks for productive activities.

22

Equity Issues in Watershed Management

'Equity' connotes fairness or recourse to principles of justice It means reducing instead of perpetuating or increasing existing inequalities This 'equal treatment' or prescribing equal shares of benefits for people in grossly unequal circumstances could be highly inequitable Equity is perhaps the most difficult objective to achieve within the context of a watershed programme and even more difficult to assess to what extent it has been achieved. If the objectives of equity are not sustained, the pressures eroding the management of the watershed resources diminish returns in the long run. The watershed management experience in Jhabua has suggested that people are unable to pursue all the three objectives of productivity, sustainability and equity at the same time. They generally responded to productivity primarily, since the risks of increased investments were lowered and linkages increased The objectives of sustainability required a greater level of intervention, since it required process for institution building, which demanded considerable time, effort and cooperation/participation from the community The issues related to equity are usually avoided as they have a very high potential for conflict and confrontation

The Jhabua experience has also suggested that though the watershed was one geographical entity in which all the landholdings, whether public or private, small or large, were interlinked, yet community was infested with various confronting factions In a community several interests collide and certain relations among groups were exploitative Loyalties are stronger at the levels of small sub-groups than at the level of the community The prevailing inequalities in the village could easily be observed in any PRA excercise or group meeting (see Chart 22 1)

Factors causing inequity

Numerous factors and reasons may result in inequitable distribution of benefits from watershed areas Some of these factors are described as follows

Chart 22.1 *Experience of a group meeting in SAMOI micro-watershed*

"When all the people had settled down, I started to observe the progress of discussions, farmers who had large land holdings, lands in the lower reaches of the watershed and belonged to the higher caste were sitting in the front Behind them sat those farmers with lands in the middle reaches and mostly not very productive lands. The land belonging to them were more vulnerable to drought and long dryspells as protective irrigation was not available to them Tribals, small land holders, farmers on upper reaches of watershed were standing in the periphery The landless, scheduled castes and women were standing on the periphery as inquisitive bystanders than as participants During discussion the domination of the upper caste land holders was easily established The decision-making power was in the hands of those who were rich, dominating and who would reap most of the benefits of the projects" (*Samoi*, 26 November, 1995)

Landless holdings

As the treatment in watershed is done on land, the farmers with large landholdings would have maximum benefits directly and indirectly The larger the landholdings, the greater the investment in conservation measures. The situation is more critical when all the investment is from the outside with little or no contribution is given as a grant In Jhabua, as in other places, the SWC measures proposed in watershed areas like field bunds were mostly favoured by the large landlholders A person with 1 ha of landholding would have a benefit of 40-180 m of field bunds as a SWC measure on a varying slope. While farmers with 3 ha landholdings on a complex slope would be benefited by 130-400 m of field bunds All these investments are provided by the WDC at the cost of other farmers Overemphasis on SWC in PPRs would create situations where direct investments have inequitable distribution due to skewed landholding patterns. With high investments in treatment on upper reaches, middle reaches and various SWC and biomass-generating efforts, most of the benefits would accumulate or percolate down to large farmers Most of the moisture controlled by SWC measure would ultimately hand up in the rich farmers' farms.

Position on upper/middle/lower reaches

The people with holdings on the upper reaches do not benefit as much from water conservation measures as those lower down The trickle down, literally, favours the better off Those with holdings in the upper or middle reaches do not benefit as much as those lower down, especially in the short term They have to loose more as the intensive treatment work in the upper reaches require a portion of private land on the upper reaches The portion of private land required, on which SWC measures are to be done, are less in lower reaches. The impact of SWC in middle reaches is not predominant in short term and is significant to farmers only if there are long dryspells during the monsoons, which may not occur every year. Impact on groundwater recharge also is not significant in upper reaches and middle reaches Similarly, topsoil from upper and middle reaches may accumulate in the lower reaches Productivity of farms in the upper reaches hardly increase, while the increase is significant (30-90%) in the lower reaches after two years Farmers in upper reaches do not adopt cash crops and dryland horticulture Soil erosion continues from upper reaches even after treatment

Inequities caused by traditional and scientific SWC measures

Traditional practices also have to be reviewed if the basis for equity is to be strengthened. The traditional practice in drought prone areas is to harvest silt, rather than to prevent erosion. The powerful sections have land in lower reaches and have resources to take up silt harvesting measures. Likewise, the traditional measure of diversion drains to protect fields from flooding is partially motivated by the objective of harvesting silt lower down even though it deprives the upper reaches of the potential to collect through protection measures, which encourage holding of water *in situ* and increase seepage. Large farmers with land in lower reaches object to conservation measures higher up as they suspect that their silt harvest would decline. Modern and scientific SWC measures like contour bunds in the fields instead of or in conjunction with boundary bunds create conflicting situations. The contour bunds would cross private farm boundaries and are considered an impediment to higher productivity. This would also create confusion in boundaries of their fields. So, some of the SWC measures/structures like contour bunds, though technically sound, are not seen as value-neutral but as partial to some and not to others. It is no use to impose a technology which demanded a level of cooperation that people are unwilling to offer, much less to sustain, since the benefits would be unequally distributed

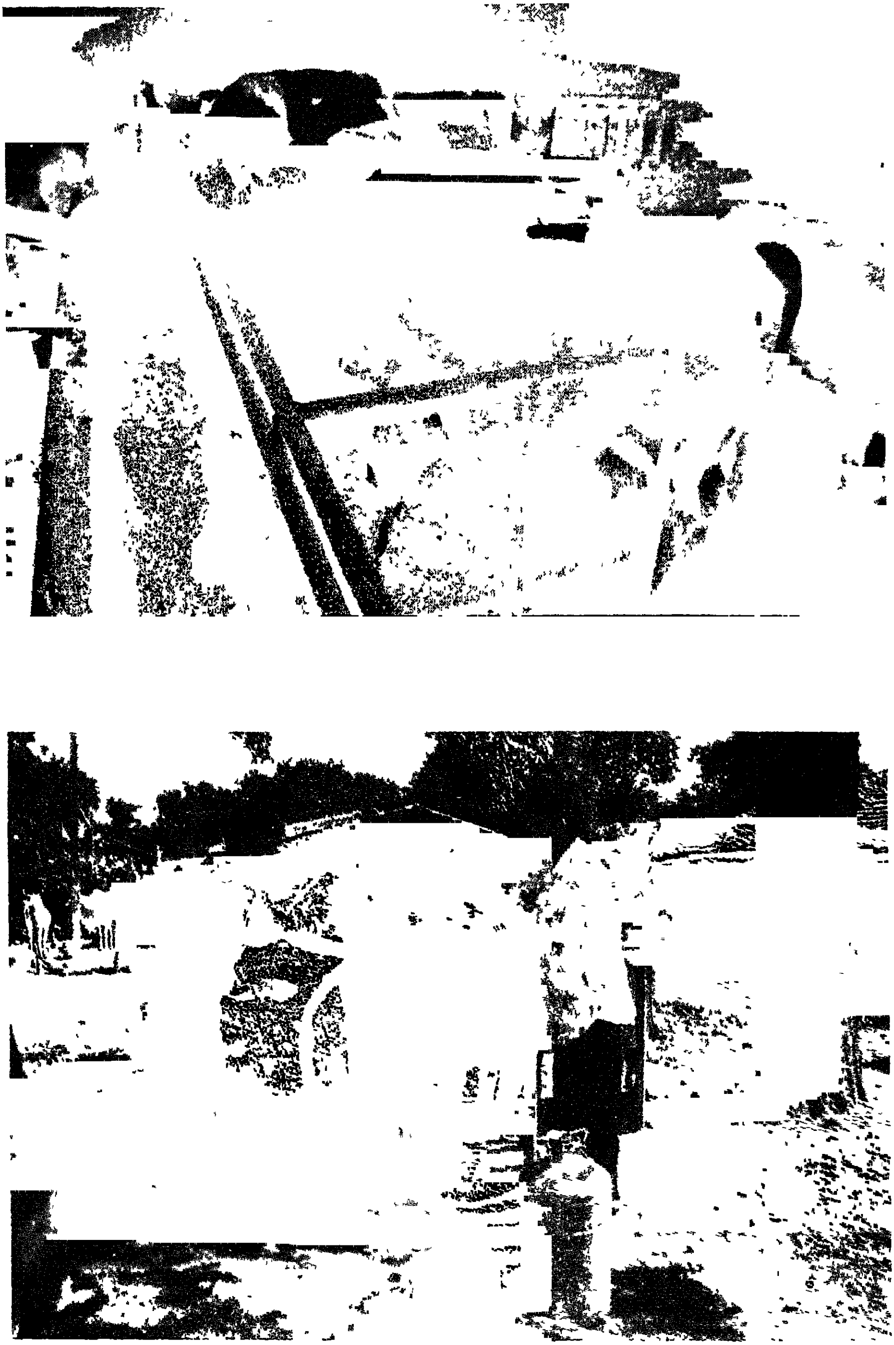
Inequity for landless

The low priority given to investment for livelihood in watershed programme tends to marginalise the landless while extending the potential productivity base of the landed, thus increasing the gap between them and the landless/marginal farmers The landless/marginal farmers have no or marginal agricultural land on slopes, which do not receive direct benefits in the form of investment in SWC or indirect benefits like *in situ* moisture availability due to water conservation measures The dependence on CPRs is high, and due to denial of open access in CPRs, in initial years as a part of biomass regeneration strategy in watershed programme, may push the landless to wall and create pauperisation trap for them It has been proved in various strategies that the landless/marginal farmers find it difficult to broaden their livelihood source base, since investment in terms of capital linkages to input sources and marketing are heavily biased towards agriculture. The resources left to create potential for livelihood in non-farm related areas are very limited

Women and inequity

Watershed interventions may benefit the community with distorted results The household may benefit, but the women in the household may not The women may have low access to credit, biomass, wages, low opportunities for income-generating activities and low facilities of drinking water, education, health, etc. Most of the times, the objectives of improving the condition or position of women are not focussed Many projects try to achieve a wide range of objectives equally, even though by its very structure and design, it is more suited to achieve some objectives rather than others It is important to ascertain that whether in the process of achieving certain limited objectives, the project has unintended results which place marginal groups in a more vulnerable position then they were previously.

Plates 63, 64, 65 (a, b) *Alternatives for landless*



Plates 63, 64, 65 (a, b) *Contd*

Inequity in wages

Evidence indicates clearly that women wages are on an average 50% less than what men earn. The difference in wages are more in agriculture, cattle caring, construction activities, as women are considered traditionally as unskilled or semi-skilled labourers. The watershed programme may inherently and unknowingly promote and perpetuate inequalities in the wages, even during implementation of WDP In agricultural lean season, the wages for landless and marginal farmers may reduce and decline due to paucity of employment avenues.

Various strategies and approaches may be adopted in watershed programmes to curtail these inequities (see Plates 63, 64 and 65 a, b).

23

Financial Management and Accounting Procedures

For execution of integrated watershed management programme, efficient maintenance of accounts and management of finances are vital issues It is not merely a question of likes or dislikes; it becomes a management and organisational responsibility to take care of accounts and finances Accounts-keeping generates information for effective financial planning and management, which in turn assists in ensuring the availability of resources and effective, purposive and integrated utilisation of those resources It is also important for meeting the statutory requirement of the programme and the organisation Accounts-keeping is the backbone for efficient monitoring

Financial management involves planning, organising and monitoring of finances of the organisation. Such management is very crucial for the DRDAs, PIAs and WDCs To be able to manage finances cost effectively, financial management, planning and monitoring should be done on a continuous basis The financial management system in an integrated watershed management programme operates on following principles

(1) *Accountability* The DRDA, PIA and WDC are accountable to the community,in general and to the government, in particular The funds for the programme should be used effectively for the cause for which it has been received by the organisation It is social and moral obligation on the part of the organisation to be accountable for proper financial management

(2) *Consistency* The financial management systems should be consistent over the years It is undesirable to keep changing systems, policies and procedures every now and then

(3) *Integrity* The integrity of the organisation should be unquestionable for proper financial management In the management of finances there should be clear-cut separation of personal and official understanding and choices Any kind of manipulation, window-dressing or understatement of reality in financial statements can raise the question of integrity Whenever there is any change in activities or expenditures, they should be reflected in the financial records of the organisation

(4) *Disclosure*· All the necessary information should be disclosed Various steps for

transparency, like keeping copies of the records at public places etc., are usual mode of disclosing it to the community

(5) *Non-deficit financing*: The programme should be run in such a fashion that planned expenditure is not higher than the planned income or grant. Non-deficit financing should involve planned expenditures and provisions to enable the organisation to meet the unplanned expenditures like inflation, taking up an unplanned activity, surviving through the period when planned funds do not come, etc.

(6) *Standard documentation*: The documents and records should be kept in the standard formats In single entry system, which is widely practised, records of debtors/creditors are maintained, but not of the goods and services for which the money goes out of or comes into the organisation. Double entry system, which is recognised as a standard recording system, recognises the fact that a transaction is a double-sided affair. For accurate results, all the transactions should be recorded in both the aspects

Systems of account-keeping

There are two main systems of accounts-keeping—single entry and double entry

Single entry system

It is the old and popular method of account-keeping among small businessmen, traders, etc. In this system, the inflow and outflow of money is recorded in a single account In this system, income or grant is recorded first and then all the expenditures are deducted An illustrative sample of single entry record in a WDC account is shown below:

January 1997		
	Balance from last month	Rs 18,000
1st Jan	Grant from DRDA	Rs 1,20,000
	Available fund	Rs 1,38,000
1st Jan	Less payment to SHG-2 (for purchasing seeds for nurseries)	Rs 3,125
	Payment to labourers (working on Nalla Bund No 18)	Rs 8,290
2nd Jan	Payment to the chairman (for attending one-day training course at block HQ)	Rs 190
4th Jan	Payment for purchasing grass seeds	Rs 14,010
	Payment to labourers (working on contour trenches on survey Plot No 136/A)	Rs 8,800
	Payment of loans to 6 SHGs	Rs 20,610
6th Jan	Payment for clearing of well	Rs 4,010
7th Jan	Payment to labourers on farm pond	Rs 8,100
	Balance	Rs 70,865

It is difficult to get information about, say, total purchase of grass seeds in a year. In this system, whatever money has been spent/received is recorded but the item on which the money has been spent are not separately recorded Even under this system of recording personal account is separately kept, otherwise it may not be possible to know how much one has to pay back to the person It is not possible to prepare 'final balance' which helps in checking arithmetical accuracy of the accounts In the absence of real and nominal accounts, the receipt and payment statement, income and expenditure statement, and balance sheet are difficult to prepare. No asset account is maintained in this system Any information obtained under this system will be dubious and doubtful.

Double entry system

This system is based on the principle that financial transactions consist of two facts (Suppose a WDC has purchased grass seeds worth Rs 14,010 The first aspect is that Rs 14,010 is paid and the second aspect is that grass seeds worth Rs 14,010 is procured) Without an outflow, there cannot be any inflow or *vice-versa*. The following sequential steps are required in a double entry system:

(a) Collection of information and its classification. For example, for each transaction, a document (like bill, cash memo, etc) is collected and classified in its 'debit' and 'credit' aspects for accounting This may be done by filling a form (voucher)

(b) Posting of accounts to the books of prime entry (e g., cashbook) with the help of these vouchers.

(c) Posting of accounts from the books of prime entry to the respective accounts maintained in the ledger. In the ledger, separate records for each item like rent, contingency expenditure, field work expenditure, etc , are maintained.

(d) Balance of all accounts maintained in ledger is extracted at the end of an accounting period and a 'trial balance' is prepared

(e) Extracting the final statement of income and expenditure account and balance sheet

Based on these two systems of accounts-keeping, a composite system should be evolved for the district or the state

Funding arrangements

All the allocations received under DPAP, DDP and IWDP must be spent on watershed development Similarly, 50% of the allocations under EAS must be earmarked for watershed development programme Watershed development should be taken on mutually exclusive basis at the village level Thus, a village/watershed would either be covered under DPAP or DDP or IWDP or EAS for its source of funding for taking up all the activities envisaged in the watershed development project. The GOI guidelines on watershed development recommended norms for different ecosystems (see Tables 23 1 and 23.2)

There should be separate watershed management account at the DRDA level, in which 100% of funds received in DPAP, DDP, IWDP allocations and 50% of funds allocated under EAS scheme should be deposited. Similarly, PIA should open a bank account for watershed funds. Based on the experience in watershed management in Jhabua, following three separate accounts should be opened by WDC

(a) *Watershed project account* The account should be operated jointly by the chairman of WDC, one member of the MDT and the secretary of WDC Chairman and secretary of WDC should be jointly authorised to withdraw sum upto Rs 10,000 Withdrawals of amount in excess of Rs 10,000 should be possible on authorised joint signatures of chairman of WDC and designated MDT member Application to the ZP/DRDA for release of funds to this account should be jointly signed by the chairman and secretary of WDC and should be duly recommended and forwarded by the project officer (PIA) All the allocations to WDC (which is around 75% of the project plan estimate) from DRDA are deposited in this account over a period of four years.

Table 23.1 *Cost norms under national guidelines for different ecosystems*

S No	*Ecosystem*	*Major problems*	*Per ha (average) (Rs.)*	*Micro-watershed (500 ha) (Rs. in lakhs)*
1	Hot sandy arid (DDP)	(i) Sand movement (ii) Degraded pasture (iii) Declining groundwater (iv) Extreme moisture stress	5000	25.0
2	Hot arid (DDP)	(i) Receding groundwater (ii) Degraded pastures (iii) Extreme moisture stress (iv) Soil erosion	4500	22.5
3	Cold arid (DDP)	(i) Deforestation (ii) Poor water management (iii) Lack of efforts on vegetable and fruit production	5000	25.0
4	Semi-arid (DPAP)	(i) Receding ground (ii) Increased moisture stress (iii) Soil erosion (iv) Lack of vegetation cover	4000	20.0
5.	Dry sub-humid (DPAP)	(i) Moisture stress (ii) Soil erosion (iii) Lack of vegetation cover	3000	15.0
6	Dry sub-humid (DPAP) (hill region)	(i) Serious soil erosion on sloping terrain (ii) Moisture stress (iii) Lack of vegetation cover	4000	20.0
7	All other areas (non-DPAP/DDP)	Areas identified outside DPAP/DDP for JRY II/EAS	4000	20.0

Table 23.2 *Phasing of watershed development expenditure (as per the GOI guidelines for the programme, the expenditure on any watershed must be spread over 4 years and over different categories of expenditure in the manner indicated below)*

	Category	*1st year*	*2nd year*	*3rd year*	*4th year*	*Total*
a	Administration	3%	3%	4%	x	10%
b	Training	3%	1%	1%	x	5%
c	Community organisation	4%	1%	x	x	5%
d	Entry point works/activity	5%	x	x	x	5%
e	Works	10%	35%	20%	10%	75%
	Total	25%	40%	25%	10%	100%

Contd

Table 23.2 *Contd*

The area that can be taken up for one watershed is about 500 ha on an average The funds for developing this area are provided at a rate of Rs 4000/ha over a four year period in the manner for EAS, DPAP are indicated in the table It works out to a total investment of Rs 20 lakhs on the development of the watershed spread over four years as follows

Phasing of watershed development expenditure for a micro-watershed

(Rs thousands)

	Categories	*1st year*	*2nd year*	*3rd year*	*4th year*	*Total*
a	Administration	60	60	80	0	200
b	Training	60	20	20	0	100
c	Community organisation	80	20	0	0	100
d	Entry point works	100	0	0	0	100
e	Works	200	700	400	200	1500
	Total	500	800	500	200	2000

The expenditure for the first year are envisaged to be spent at different levels and for different categories as follows

(Rs thousands)

	Category	*Village*	*WDT*	*District*	*State*	*Total*
a	Administration	25	18	7	10	60
b	Training		30	10	20	60
c	Community organisation	60	5	10	5	80
d	Entry point works	90		5	5	100
e	Works	200				200
	Total	375	53	32	40	500

Release of project funds by DRDA

Year	*Instalment*	*%*	*Agency*	*(%)*	*Component*	*% Breakup*
1st	1st	15%	PIA	15%	(1) Admn cost (2) Comm orgn (3) Training (4) EPA	3% 4% 3% 5%
	2nd	10%	WDC	10%	Works	15%
2nd	1st	20%	(1) PIA (2) WDC	5% 15%	(1) Admn cost (2) Comm orgn (3) Training (4) Works	3% 1% 1% 15%
	2nd	20%	WDC	20%	Works	20%
3rd	1st	15%	(1) PIA (2) WDC	5% 10%	(1) Admn cost (2) Training works	4% 1% 10%
	2nd	10%	WDC	10%	Works	10%
4th	1st	10%	WDC	10%	Works	10%

(b) *Watershed development fund account*: The WDC should open another account in the name of watershed development fund. This should be a fixed-deposit/interest-bearing account and shall be jointly operated by president of WA, chairman of WDC and project officer of PIA. During the project period, it is not expected that any money will be withdrawn from this fund for taking up repairs/maintenance or further development of any completed project works/activities Contributions received from user group members and individual beneficiaries in cash or the monetary equivalent of material shall be taken from the watershed project account and transferred to the watershed development fund. At least 5% of the wages from SC/ST beneficiaries and 10% of the wages from other beneficiaries should be deposited. Any other cash collections made by the WA and WDC in terms of donations/contributions/recoveries of fines or fees for services rendered, etc. shall be deposited in this fund. The fund shall be used for post-completion operations and maintenance of community works/activities, such as community engineering works, maintenance of pasture lands, forests, fishery tanks, etc , payment of emoluments to secretary and volunteers of WDC. However, it shall not be used for repair/maintenance of individual works on private lands. The WDC should be competent to charge fees or other contributions/donations from users. Sale proceeds or disposal amounts of intermediate usufruct rights etc shall be deposited in this fund

(c) *Gramkosh* Depending upon the mobilisation of the community, higher contributions could be gathered from individuals or groups For example, 50% contributions are very much possible from expenses done on PPR(contour bunds in agricultural land, control measures for gullies in the fields etc.). Similarly, contributions from labourers working on CPRs (digging-contour trenches etc.) and from SHGs benefited from revolving fund may also be deposited in *gramkosh* This fund completely belongs to the community and the WDC. It may be used for development and welfare of the community on the recommendation of WDC and WA.

Expenditure can be authorised from watershed project account to the extent of Rs 1000 by the secretary WDC, upto Rs 10,000 by the WDC and above Rs 10,000 by the WDC after specific approval of the concerned technical member of the MDT However, the withdrawals through joint signature should only be according to the procedure described earlier

Maintenance of accounts

The DRDA, PIA and the WDC should ensure that accounts of their activities and expenditures are maintained in accordance with the formats prescribed by the DRDA The DRDA are advised to consult PIAs before designing formats for maintenance of accounts. Each PIA member should also maintain proper documentation of the processes and activities that are undertaken at the watershed level and the project level This will enable outside independent agencies to analyse the problems of attitudes, skills required, behavioural aspects and procedural bottlenecks and suggest necessary improvements For this purpose, the district WAC should workout formats for logbooks and diaries to be maintained at the watershed level The records recommended to be maintained at various levels are shown in Table 23.3 The list is illustrative and modifications may be undertaken

Table 23.3 *Recommended records to be kept at various levels*

	At DRDA level		*At PIA level*		*At WDC level*
(1)	Voucher folder	(1)	Voucher folder	(1)	Voucher folder
(2)	Cashbook	(2)	Cashbook	(2)	Cashbook
(3)	ledger	(3)	Ledger	(3)	Grant/expenditure register (project account)
(4)	Cheque register	(4)	Cheque register	(4)	Cheque register (project account)
(5)	PIA register	(5)	Advanced register	(5)	Cheque register (development account)
(6)	WDC register	(6)	Salary, honorarium register	(6)	Contribution register
(7)	Training register	(7)	Estimate/Action plan folder	(7)	Measurement book
(8)	Report register	(8)	Membership register	(8)	Advanced register
(9)	Registration ledger	(9)	Report register	(9)	Action plan folder
(10)	Membership register	(10)	Meeting proceeding register (to be maintained by project assistant/accountant of PIA)	(10)	Membership register
(11)	Meeting proceeding register (to be maintained by account officer of DRDA)			(11)	Report register
				(12)	UG/SHG register
				(13)	Meeting proceeding register (to be maintained by Secretary of WDC)

Following recommendations are made for maintenance of accounts based upon the experiences in watershed management operations in Jhabua

(1) *Cashbook*

(a) Entries of all the transactions must be depicted in the cashbook as soon as the transactions are over. Officer-in-charge should cross-check it with attested vouchers and should counter sign it every day

(b) Balance amounts should be calculated every day and should be entered at the bottom of the closure of accounts

(c) Officer-in-charge should cross-check the balance amount at the end of every month

(d) Overwriting on entries should be avoided If there is any fault, then entry should be cancelled with red ink and correct entry should be written and initials of the officer-in-charge should be marked close to it

(e) Cash withdrawn from the bank/treasury should not be kept unused in the office. Appointment of contingent staff for carrying cash from the bank should be discouraged

(f) Separate cashbook should not be maintained in office A single cashbook for watershed activities is sufficient

(g) A certificate on the first page of the cashbook should be written by the officer-in-charge Pages in the cashbook should be numbered

(h) Accounts in the cashbook should be closed at the end of financial year Balance on 31st March should be carried forward as opening balance in a fresh cashbook.

(i) Interests should be entered into different columns of the cashbook from time to time

(j) Cash withdrawn should be judiciously used within 24 hours of withdrawal

(k) If some amount is left unutilised or saved, then it should be deposited in the bank.
(l) Cash payments should be avoided as far as possible. Payments of more than Rs. 1000 should be paid by account payee cheques.
(m) Receipt of payments should be taken on vouchers and should be filed systematically.
(n) Advances should be discouraged.

(2) *Vouchers*

(a) Purchased items should be recorded in the stock register.
(b) Payments on any purchases should only be done after ascertaining the quality and the quantity of the supplies.
(c) Officer-in-charge should mark , "Pass for Payment" on the overleaf and sign.
(d) No payment should ever be made in absence of supporting bills or vouchers.
(e) Muster rolls/acquittance rolls, etc., should be cancelled and signed by officer-in-charge after due payments.

(3) *Advances*

(a) Advances for watershed works or activities should be discouraged
(b) If advances are made due to compelling reasons, then it should be adjusted within 15 days.
(c) Entries of advances should be made in red ink in the cashbook. Entries should also be recorded along with purpose in the advances register.

(4) *Purchases*

(a) No unnecessary purchases should be made. Similarly, purchases should be assessed on the basis of requirement and availability of funds.
(b) Sanctions regarding purchases should be taken from competent authority before initiating the process
(c) If purchases are worth less than Rs 10,000 quotations from all the authorised manufacturers or suppliers should be invited. For more than Rs 10,000 tenders should be floated in regional newspapers
(d) Costly furnitures, typewriters, coolers, air-conditioners, computers, vehicles, etc., should not be purchased without prior permission of DRDA/WAC.
(e) All the purchases should be entered into the stock register and should be countersigned by officer-in-charge.
(f) Purchases from government corporations and agencies should be preferred.
(g) Payments should be made only after ascertaining the quantity and quality of supplies

(5) *Salaries*

(a) In no circumstances, salaries more than the prescribed salary should ever be paid
(b) Payments of salaries/honorariums should be made after recording it in the acquittance rolls
(c) Payments should be made on the basis of attendance certificate. The principle of "no work, no pay" should be strictly followed

(6) ***Action plan***

(a) Action plan should be prepared on the basis of prevalent schedule of rates
(b) Work according to the action plan should only be started after receiving technical sanctions and administrative approvals from competent authority.
(c) If the cost-overrun is expected, then supplementary proposal on solid grounds should be prepared. In no situation, cost-overrun should be allowed.
(d) Completion certificates should be obtained and should be registered.

(7) ***Labour payments***

(a) Payments of labour charges should be made by competent person in presence of chairman and secretary WDC, sarpanch etc.
(b) Receipt by signature or thumb impression should be insisted.
(c) Minimum wages should be ascertained. Payments should be made on the basis of task performed

Similar or modified rules could be prepared and implemented by DRDA for vehicle repairs, POL, stationery, travelling allowances, refreshments, loans, etc Entries in registers should be recorded for following purposes (illustrative).

(i) At DRDA level

(a) Allocation from Government of India and State Government for watershed activities. voucher, cashbook, ledger
(b) Interests received on allocated funds: voucher, cashbook, ledger.
(c) Allocation of funds from DRDA to PIA voucher, cashbook, ledger, PIA register, cheque register
(d) Allocation of funds from DRDA to WDC. voucher, cashbook, WDC register, cheque register.
(e) Expenses on trainings of MDT/WDC members voucher, cashbook, ledger, training register, cheque register
(f) Registration of PIA/WDC: registration register
(g) Reports received from PIA: reports register

(ii) At PIA level

(a) Allocations received from DRDA· voucher, cashbook, ledger
(b) Interests received on allocated funds: voucher, cashbook, ledger.
(c) Expenses on salaries and honorarium: voucher, cashbook, ledger, honorarium register, cheque register.
(d) Advances to SHGs. voucher, cashbook, ledger, advances register

Separate records of administrative expenses, community organisation, training, entry point activity should be kept

(iii) At WDC level

(a) Allocations received from DRDA/PIA voucher,cashbook, grant/expenditure register.
(b) Interests received on allocated funds voucher, cashbook, grant/expenditure register.
(c) Transfer of fund from project account to development account due to contributions. voucher, cashbook, cheque register (project account)
(d) Expenses on work voucher, cashbook, cheque register (project account), measurement book, grant/expenditure register, advances registers
(e) Assistance to SHG voucher, cashbook, contribution register, SHG/UG register

(f) Distribution of watershed cards: watershed card register.
(g) Proceedings of weekly meetings: meeting register.

It is important to devise fortnightly or monthly reporting formats for PIA and WDC. It should be designed in such a manner that physical and financial progress could be monitored.

Regular inspection and audit of PIA and WDC records should be carried out Inspection of activities and works of PIA and WDC may be undertaken by teams of APO (DRDA) or teams of Deputy Collector (revenue) etc. Audit of PIA records should be undertaken once in three months by a team consisting of accounts officer, APO (watershed) and accountant (watershed) of DRDA. A chartered accountant may be hired by DRDA to audit PIA funds every quarter. As the number of WDCs is very large, so accountants of block development office, block education office and Tahsildar/Mamlatdar office may be selected and trained. On a fixed honorarium, they may be entrusted with audit work of WDC every three months. Actions on audit findings should be quick and stern.

24

Monitoring and Evaluation in Watersheds

Monitoring and evaluation functions are presented here in the context of the planning, implementation and completion of an integrated watershed development project

Monitoring is an internal and inherent project activity and consists of diagnostic studies which help in decision making and policy changes. Evaluation, on the other hand, is the assessment of a project's performance and impact on the area and target population Monitoring and evaluation serve the purpose of surveillance for the benefit of funding authorities. But they also have other widespread ramifications.

Monitoring is a continuous assessment of the functioning of the project activities in the context of implementing schedules and of the use of project inputs by targeted population. It is an integral part of day-to-day management. Monitoring is the process of observing, measuring and reporting objectively on the benefits that usually appear during the life span of the watershed project. It is essentially the systematic measuring of objectively verifiable project indicators to determine the extent of the gains toward the stated objectives. Monitoring should be specific and done at frequent intervals (monthly, quarterly or annually) to allow project activities to be adjusted as they go along WDC, PIA and DRDA should have special monitoring tools and system, and tables for recording monitored data. The monitoring set-up involves·

— defining the objectives of the monitoring system,
— designing a programme to systematically monitor achievements,
— selection of indicators/parameters to be monitored, the location, methods/processes and frequency of observations, and the information processing and reporting procedure are important, and
— organising, motivating and training people to obtain, convey and use the information.

Evaluation, on the other hand, is a periodic assessment of the relevance, performance, efficiency and impact of the project in the context of its stated objectives. It involves comparisons requiring information from outside the project, as well. Evaluation is the process which seeks to analyse and make sense of the data compiled through monitoring. Evaluation organises and appraises the information gathered by monitoring and integrates it with information gathered in other ways and presents the results in an appropriate form and at a place and time that is most beneficial to the planners. So, in short, evaluation extracts information from a mass of observational data and presents it in a form that is easy to understand and use. Evaluation may require additional studies or research to obtain information not provided by project monitoring and evaluation analysis. There is a cause and effect relationship between the remedial measures and the short, medium and long term benefits; and it compares the monitored data with idealised presumptions.

Monitoring in an integrated watershed development project helps to:

1. Identify the targets and goals for the project implementation and the indicators to measure progress against these.
2. Summarise and disseminate the information flowing from various field officials and PIA members.
3. Collect and analyse data from the intended beneficiaries of the project for the purpose of supplementation and complementarity.
4. Identify problems and obstacles encountered by the project and conduct diagnostic and therapeutic studies for the remedial measures.
5. Maintain various data series over time for the purpose of later evaluation.
6. Prepare report and indicate range of logical options. Based on the data-base created during the monitoring, evaluation encompasses additional processing supplementary with impact studies and reviewing the information over an extended period to judge achievement.

Watershed development projects are (a) physical delivery-oriented, and (b) people-centered. Monitoring and evaluation of people-centred goals are more difficult as the goals are less tangible (for example, judgement of level of participation of beneficiaries in the watershed project is quite a subjective entity). Similarly, changes in behavioural patterns of a beneficiary concerned are difficult to ascertain and measure, as prediction of weather, in what way, at what rate and in what direction is uncertain. Hence, the target specification is less than perfect. So, besides monitoring of physical and financial targets, data and information regarding linkages between the project implementing agency and the target population are needed.

Evaluation

Internal on-going evaluation is continuous and non-stop process and is not an *ad hoc* excercise. It does not involve much data collection. On-going evaluation focusses on

- What is the response of the project beneficiaries to the inputs, services and other assistance ?
- What are the effects of the project on agricultural production, fodder and fuel production in the watershed area ?
- Is the project having consequences which were not anticipated ?
- Does the intervention model on which the project is based remain valid in a changing environment?

Monitoring focusses more on implementation issues, whereas on-going evaluation addresses the likely outcomes of the interventions. It provides systematic feedback facilitating the integration of the evaluation process into the management system. The recommendations emerging out of internal on-going evaluation are more comprehensive, practical and relevant. However, it cannot replace or substitute for external evaluation/formal evaluation.

Formal evaluation processes are required for:

(1) *Decision-making*: Project managers or PIAs need to be able to identify project's strengths, weaknesses, constraints, opportunities, impact and its relevance to the individual, community and nature in order to make sound decisions (realistic and relevant decisions concerning methodology, training, staffing, logistic and other aspects of project management)

(2) *Improvement of performance*: Managerial, financial, ecological, beneficiary coverage performance could be improved by the feedback from evaluation results.

(3) *Personnel evaluation*: Objective assessment of the performance of project staff (PIA members, WDC secretaries, Project coordinators, community organisers, volunteers, etc.) is required by the project managers.

(4) *Allocation of resources*: Prioritisation of resources like time, money, personnel, material, etc., is essential and the result of an evaluation help us to determine how our limited resources could be used most effectively

(5) *Programme justification*: Participants, implementors and funding agency (say DRDA) can make judgements regarding the project direction and impact

(6) *Determination of policy*: Project managers could modify, expand and abandon approaches and modalities tried out in the policy implementation.

Evaluation for whom?

(1) *Community members involved in the project*: It is in their best interest to achieve the goal of improvement in the quality of their lives and the objective of the watershed programme to be need-based.

(2) *Community members not yet benefiting from the project*: As it would open new horizons for extending the project benefits to nearby villages/villagers. Evaluation would also help replicating the project in adjoining areas

(3) *Project staff*: Objective information regarding the speed and direction of the project and their role performance as facilitators, trainers, extentionists, administrators, etc., could be gathered. This may give them positive rewards or it may point out areas for improvement.

(4) *DRDA, state headquarters*: Funding agencies would like to reinterpret their policy interventions of the programme and would like to assess the impact

All the groups indicated above are 'partners' and that each group has an interest in participating in the evaluation process and that all will benefit from the findings.

Designing a watershed monitoring system

Basic considerations

Monitoring and evaluation systems may turn out useless because the people providing, conveying and using the information are not sufficiently motivated and the project staff is not properly organised or trained in applying the procedures. Thus motivational and procedural/technical training is important and necessary. The project staff selected should be vigilant, observant and adaptable. Appropriate training for the staff assigned in gathering, processing, storing and disseminating the field data should be ensured. The monitoring system design should actively involve the project staff, the community and the representatives of institutions and enterprises interested in watershed management. The system should be developed through intensive and extensive meetings or workshops with the people concerned. Practically, the monitoring system design should be able to answer following key questions:

(a) What do we want to achieve?
(b) Which indicators or indices do we measure?
(c) Where do we monitor the indicators?
(d) Which methods/tools/techniques should be used?
(e) What kind of precision and accuracy do we require?
(f) How often and for how long do we monitor?
(g) Who monitors?
(h) How do we process and analyse the information?
(i) How do we convey the information?
(j) How much will be the cost of the system?

Phases in the formation and execution of a monitoring and evaluation system

Every project monitoring design should include an appropriate system to monitor the objectives, activities and benefits stated in WDP. While formulating the system's objectives, we should be able to get the opinions of all the people involved in the project (e g , farmers, artisans, agricultural labourers, womenfolk, female extension agents, experts, technicians, engineers, representatives of institutions and enterprises, etc.). They should be encouraged to participate in useful and responsible manner.

Phase-I Identify the needs and the objectives· Management and technical staff of the project should be aware of the importance and the needs for a monitoring and evaluation system. Stated objectives and goals of the project should be explicitly clear to them

Phase-II. Promotion of the value of monitoring: Management, technical and professional staff involved in the project should convey their awareness and motivation to the WDC secretary, chairman, volunteers, members and watershed community If the community is not convinced about monitoring system, then the system is bound to fail. All the people involved in the project (staff or community) should be able to support and constructively criticise the project's stated objectives and expected benefits This approach should result in the collection, processing and transmission of accurate, precise, reliable and timely information.

Phase-III Designing the system Work on designing the monitoring and evaluation system may commence as soon as the management plan is available After review of the watershed management plan, main and intermediate objectives should be identified The treatments and activities needed to attain each of the intermediate or main objectives should be assessed Following problems are usually confronted at this juncture (as experienced in Jhabua).

— insufficient staff assigned to monitoring,
— funds allocated or reserved for monitoring have been diverted and spent in other activities/items,
— monitoring locations are widely dispersed and remote, leading to logistical bottle-

necks,

- DRDA/PIA expects practical information,
- staff is not properly trained to carry out the processes and
- community looses interest in community-based monitoring over a period of time.

Thus, it would be appropriate to try and design simple, inexpensive monitoring and evaluation systems, in line with the scope and needs of the project.

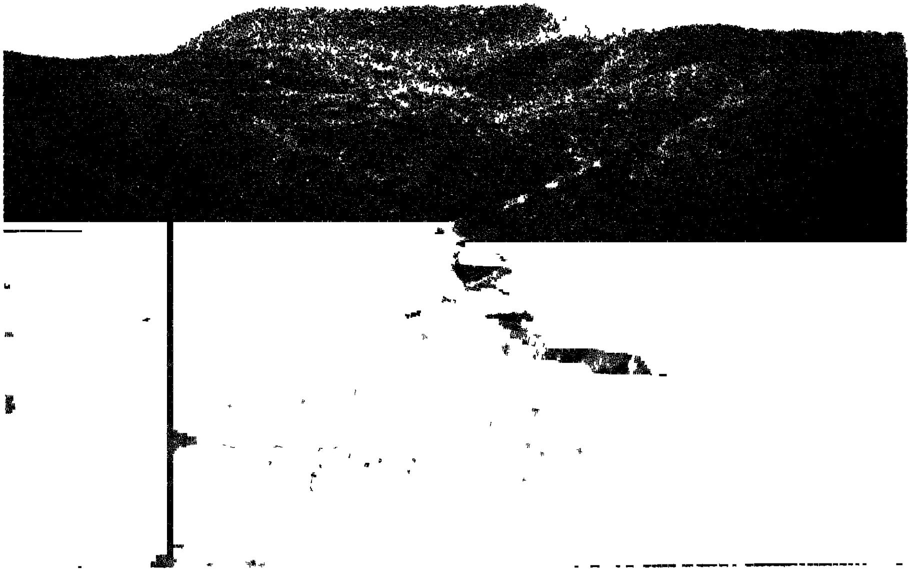
Phase-IV Organizing implementation: A well-thought organisational structure including staff, procedures and technical capacity to implement it should be created/evolved. A proper match between monitoring system design and available organisational structure should be tried The monitoring system should be flexible and capable of undertaking new activities and responding rapidly to changes.

Phase-V Managing the monitoring system: The information obtained in the field should be processed and conveyed in a timely and reliable manner to every level of management that needs it

Phase-VI Evaluating the monitoring system. There should be periodic assessment and evaluation of the monitoring system to decide whether it should stay as it is or should be adjusted/modified There should be a constant watch on whether the information provided is in fact the information the user wants

A WDP seeks to achieve the main and intermediate objectives which vary from case to case (see Plate 66). For attaining these objectives a number of activities resulting in short, medium or long term benefits are possible A monitoring system should identify one or more of the most significant benefits that each of these activities will produce. Each of the

Plate 66 *The most crucial and difficult aspect in watershed management is maintenance and care after the project period is over Sustainability can be ensureed by community mobilisation and institution-building*



expected benefits may have one or more measurable indicators. We select the most representative indicator, for example, one of the main objective of watershed programme is reducing soil erosion, for which numerous soil erosion control activities like gully control measures, sediment traps, trenches, etc., are taken up which result in reduction of soil loss. This can be monitored by measuring sediment yield in the downstream reservoir.

The indicators may be monitored on slopes/hillsides or in flow channels. Indicators quantifying the socio-economic and environmental achievements may be monitored on farms, slopes or hillsides. While indicators which quantify hydrologic benefits associated with water yield, runoff quality, water regime and sediment delivery are monitored in flow channels.

Monitoring tools

Numerous monitoring tools are available to quantify the changes in indicator values over time. Some of the commonly used tools are given below·

(a) Semi-structured interviews.
(b) Community workshops to evaluate the extent of adoption and resulting achievements from conservation practices
(c) Observation and measurement of easily quantifiable field indicators (like soil denudation, advance/reduction of gullies, land use changes, channel scouring etc.).
(d) Farmers' own records can be prepared (which are logbooks to record simple and easily observable changes on their farms) These records provide vital information in great detail
(e) Ground photographs taken from the same place depicting before and after remedial measures, details concerning landscape CPR's, changes in the status of natural resources
(f) Community evaluation of certain simple technical (e g , sediment yield), ecological (e.g., fodder productivity), economical (e.g., change in quality of living standard/crop productivity), social (e.g., involvement of SHGs/UGs), essential services (e.g , attendance in schools) indicators
(g) Remote sensing satellite imageries and aerial photographs taken at the start of the plan and repeated periodically.
(h) Geographical information systems (GIS).
(i) Video monitoring.
(j) Comparison with demonstration and research plots/farms.
(k) Comparison with demonstration and research micro-watersheds.
(l) Hydro-meteorological measuring.
(m) Using the information gathered by other institutions and private enterprises
(n) Combination of above mentioned tools.

Selection of indicators

Choosing proper indicators is crucial to setting up effective monitoring and evaluation Criteria for effective indicators include

1. *Unambiguous definition.* The indicators must be clearly defined in the project's context.

2. *Consistency*: The values of the indicators should stay constant as long as they are collected in identical conditions, no matter who does the collecting. Indicators should be chosen to give objective rather than subjective data.

3. *Specificity*: Indicators should measure specific conditions that the project aims to change (e.g , the delivery of agricultural inputs is specific, while crop output is not).

4. *Sensitivity*: Indicators should be highly sensitive to changes in project situation.

5. *Ease of data collection*: The collection of the data needed to calculate the chosen indicators should be within the capability of a limited team. The fact that an indicator is important does not necessarily mean that it is practical to measure it.

The selection of the indicators that will be used to judge watershed project achievements is critical for the conduct of an evaluation. Appropriate indicators help in evaluation by·

1. Revealing the nature and rate of change that has occurred or appears to be occurring.
2. Enabling progress to be compared with the planned targets.
3. Assisting in input-output and cost-benefit analysis

Indicators have a limited contextual relevance and do not possess universal validity. A valid indicator in Jhabua might be invalid in Idduki district of Kerala. Appropriate indicators for evaluating a project should be determined at the early implementation stage, so that arrangements can be made to collect the necessary data. The number of indicators should be kept to a bare minimum. Evaluation should not and cannot always depend on quantitative indicators Quantitative indicators cannot be constructed for a number of vital consequences. Qualitative indicators should also be used to evaluate social consequences.

The United Nations emphasised and considered various aspects in choice of indicators. It emphasised that aggregate indicators cannot be divided into sub-categories. Household data indicators are costly to collect. Not all concepts lend themselves to relatively simple, quantitative construction of indicators Examples are the degree of community participation or organisational structure Rather than trying to squeeze these complex concepts into a small set of numbers, descriptive statements might be prepared with indications of the direction of change. The number of indicators must be limited to keep information requirements and costs of collection to a minimum and to ensure focus on the most significant issues Both indicators and related information requirements should be periodically reviewed to take into account changing needs or refinements in data quality. As far as possible the indicators, or at least some of them should be divisible by gender, income groups, etc , in line with objectives Disadvantaged groups, such as the rural poor, landless and women may not receive equitable benefits from watershed projects The final selection of monitoring indicators should depend upon factors like the objective of the monitoring system, the treatments implemented, the scale of the project and the amount of funds available

An illustrative list of indicators used in watershed management evaluation studies is shown in Chart 24 1.

The common practice is to carry out evaluations at one or more of four stages of a watershed project·

(a) At the planning stage to give us benchmark data on the variables or indicators that we wish to monitor and evaluate This provides reliable initial or baseline data on climatological, economical, social, physical and biological variables *(baseline evaluation)*.

Chart 24.1 *Illustrative list of evaluation indicators*

(I) *Institutional-building and community organisation indicators*

(1) Presence of rural development institutions in the watershed (+)

(2) Coordination among different institutions (+)

(3) Financial independence and sustainability in created institutions (+)

(4) Capacity-building in the institution to resolve managerial, administrative and financial problems (+)

(5) Number of trained professionals assigned to the project (+)

(6) Number of welfare and development programmes implemented or adopted by institutions (+)

(7) Private funding or donations to project activities (Rs /year) (+)

(8) Number of farmers trained in soil conservation/modern agriculture techniques/allied activities (+)

(9) Number of operational and/or functional grass-root community organisations (+)

(10) Percentage of population willingly adopting one or more conservation practices (+)

(11) Percentage of population willingly adopting appropriate technology to improve crop, livestock, water harvesting, etc (+)

(12) Group performance of SHG's, UG's and WDC's (+)

(II) *Technical indicators*

(1) Extent of soil loss (tons/hectare/year) (-)

(2) Extent of runoff (cum/sec) (-)

(3) Levels of sediments in flowing water at watershed outlet (mg/liter) (-)

(4) Water discharge in the stream(cum/sec) (+)

(5) Rise in water table (+)

(6) Increase in the yield capacity of wells (gallons/min) (+)

(7) Change in soil moisture (+)

(8) Annual water flow (m^3/sec) (+)

(9) Annual flood peaks(m^3/sec) (-)

(10) Suspended sediment concentration(mg/l) (-)

(11) Sediment yield (tons/km^2/year) (-)

(12) Mean turbidity (standard units) (-)

(13) Biological and chemical properties of water (+)

(14) Normal pH value (=)

(15) Mean pesticide concentration (ug/l) (-)

(16) Sedimentation in the reservoir downstream (m^3/year)(-)

(III) *Ecological improvement indicators*

(1) Biomass index (+)

(2) Biodiversity index (+)

(3) Overutilised land (ha/year) (-)

(4) Severely eroded land (ha/year) (-)

(5) Land under shifting cultivation (ha/year) (-)

(6) Wastelands (ha/year) (-)

(7) Overgrazed land (ha/year) (-)

(8) Stabilised slopes (ha/year)(-)

Contd

Chart 24.1 *Contd*

(9) Treated gullies (ha/year) (+)
(10) Number and depth of gullies (-)
(11) Soil fertility (cationic exchange capacity and percentage basic situation (+)
(12) Soil organic matter content (+)
(IV) *Natural resource/CPR use indicators*
(1) Crop productivity (kg/ha/year) (+)
(2) Fodder crop productivity (kg/ha/year) (+)
(3) Pasture land productivity (kg/ha/year) (+)
(4) Productivity of fuelwood/small timber from plantations (m^3/ha/year((+)
(5) Milk production (litre/ha/year) (+)
(6) Community forestry woodlots for fuelwood (ha/year) (+)
(7) Managed agro-forestry systems (ha/year) (+)
(8) Managed agro-horticulture systems (ha/year) (+)
(9) Protected degraded forest land by social fencing (ha/year) (+)
(10) Unprofitable crop land (ha/year) (-)
(11) Unprofitable grazing land (ha/year) (-)
(12) Unused area with agro-forestry potential (ha/year) (-)
(13) Area of CPR's (ha/year) (=/+)
(V) *Economic and social indicators*
(1) Change in household income (Rs/household) (+)
(2) Change in household expenditure (Rs/household) (=\+)
(3) Change in household savings (Rs/household) (+)
(4) Change in living standard (+)
(5) Number of families moving above/below poverty-line (+/-)
(6) Extent of migration in search of employment (-)
(7) Prevailing wage rates in agriculture and non-farm sector (+)
(8) Extent of indebtedness in cash or kind (-)
(9) Change in crop production (+)
(10) Change in double-cropped area (+)
(11) Change in agricultural and non-agricultural land values (Rs/ha) (+)
(12) Number of mandays generated per year (+)
(13) Number of women/young people per year participating actively in grassroots organisations (+)
(14) Time spent collecting wood (hrs/month) (-)
(15) Time spent fetching water (hrs/month) (-)
(16) Annual requests for technical assistance (+)
(17) Diversification of product range and skill-upgradation of rural artisans (+)
(VI) *Essential services indicators*
(1) Literacy rate (+)
(2) Number of schools/year in operation (+)
(3) Percentage of school-age children attending school (+)
(4) Dropouts from primary schools (-)
(5) Level and extent of prohibition (+)

Contd

Chart 24.1 *Contd*

(6) Percentage of houses/year with electricity (+)
(7) Percentage of houses/year with drinking water (+)
(8) Number of dispensaries/year in operation (+)
(9) Number of families/year receiving medical care (+)
(10) Annual mortality rate (-)
(11) Infant/Maternal mortality rate (-)
(12) Percentage of 0-16 years population covered under immunisation programmes (+)
(13) Percentage of target couples protected under family planning/welfare measures (+)
(14) Number of sterilisations/year (+)
(15) Annual birth rate (-)
(16) Level of malnutrition in below one year age group (-)
(17) Number of kilometres of road/track motorable all year round (+)
(18) Fuelwood availability (m^3/year) in forests (+)
(19) Availability of essential commodities (+)
(20) Awareness regarding various welfare/development programmes (+)
(The symbol (+) indicates that the project is aiming to increase the value and the symbol (-) shows that it is trying to decrease it)

(b) In the middle of implementation, when the watershed project has overcome the teething problems, the flow of services and inputs to the target population has commenced and its initial responses can be observed The purpose of such intermediate evaluation is to check on the effectiveness of each individual activity or treatment and the project as a whole, and to measure the short and medium term benefits *(mid-term evaluation)*

(c) At the end of the project's economic life to document the efficiency of project implementation, the accuracy of project estimates and medium and long term benefits *(terminal evaluation)*

(d) Several years after the projects termination (5, 10 or 15 years after the project termination), when its long-term effects and impacts are visible *(post-terminal evaluation)*

In traditional approach, the evaluation is done mainly by the projects technical staff (outsiders) On the other hand, in the participatory approach, PAME (participatory monitoring and evaluation), the local people (insiders) are actively involved in the design of the monitoring system and in the processing, analysing and evaluation of the data obtained The monitoring and evaluation system may be evolved for micro-watersheds, milli-watersheds, sub-watersheds, district or state Thus, they may be applied to a single farm or to an entire state

Economic indicators

The Integrated Watershed Development Programme envisages a change in social and economic conditions of the beneficiaries The primary objective of a watershed intervention is to catalyse sustained economic growth in project areas and to alienate poverty The economic indicators are more specific and change in their values and direction could more easily be adjudged But, economic indicators are not without ambiguity There is a widely prevalent difference in opinion about how to define them and how to use them in a project area

Household income

Small landholders are the main groups which would receive maximum inputs and services that are designed and built in the watershed programme to increase production and productivity To a certain extent landless labourers and rural artisans also benefit. Allied agricultural activities like dairy, fisheries, mushroom cultivation, sericulture, apiculture, etc., would also result in increased household incomes Non-farm activities like handlooms, handicrafts, small rural manufacturing units etc would add into the incomes Non-agricultural works would benefit from the expanded opportunities created in sectors, such as, transportation, processing, marketing, etc Despite favourable aggregate results, the level of increase in household income would differ and also there would be households with stagnating income levels or fall in their monthly incomes Evaluation of the economic benefit of particular crops or products could be satisfactorily done Measurement of total farm or household incomes are extremely difficult There are definitional problems caused by factors like valuation of labour inputs and consumption of home productions Similarly, response problems create difficulties in the assessment The income of each household member is difficult to obtain from a single respondent; incomes from informal activities like small-scale trade or small production units are difficult to cover in an income survey, sporadic marketing may result in erratic income generation Often objective responses are difficult to elicit in an income survey Income survey formats should include queries about visible and invisible incomes from primary, secondary and tertiary sectors

Household expenditure

In the measurement of expenditure, some of the definitional and response problems seen in income evaluation could be curtailed Expenditure can be assessed accurately if the recall and reference periods are appropriate Casual daily expenditures such as expenditure on cigarettes/*bidis*, alcohol, fuelwood, milk, etc., could be appropriately evaluated for a recall period of 2-3 days or at most a week Items such as expenditures on household provisions, school fees and rent, services and entertainment may need reference period of one month Irregular major expenditures such as expenditures on health, household repairs, farm activities may have annual reference Prestige expenditure on social occasions like festivals, marriages, birth/death ceremonies, etc, should also be included in expenditure survey

Changes in expenditure levels, in most cases, reflect changes in income fairly accurately Expenditure surveys may require multiple visits for an extended period It may also require multiple interviews in a household It is advisable to conduct a one to two week survey (with numerous visits within a period) and which could be repeated at certain selected times in the year

Household savings

Household savings could be easily evaluated Household savings survey along with expenditure survey could fairly depict the income levels Savings could be ascertained by a well-prepared survey format Savings invested in jewellery, precious stones, land, shares, etc., should be included

Measurement of living standard

The economic change in a household could be evaluated fairly easily from

(a) *Quality housing and related facilities*, e g., covered area and number of rooms, type of construction material, nature of the roof, access to potable water, location of bathrooms within the dwelling.

(b) *Acquisition of durable possession*, e.g., bedding, clothing, footwear, cooking utensils, basic furniture and sundries like watch, radio, television, bicycle, etc.

(c) *Availability of community facilities*, e.g , access to primary health facilities, all-weather roads, primary schools, markets, etc.

Following 15 indicators were selected for a study of impact evaluation in watershed villages in Jhabua district:

1. *Household income:* in cash and kind from all sources.
2. *Level of indebtedness* in cash and kind from all sources.
3. *Type of house*: (a) thatched roof and mudwalls, (b) thatched roof and unburnt brick or softwood walls, (c) thatched roof and brick, stone or hard timber walls, (d) tiled roof with mud, brick or stone walls, and (e) concrete structure.
4. *Furnishing* (a) bare essentials, (b) sparse, (c) moderate, and (d) sufficient
5. *Sanitation* (a) open air (b) covered pit, (c) borehole with water seal, and (d) flush toilets.
6. *Electricity* (a) extent of electrification in house, and (b) commodities run on electric power.
7. *Water* (a) unprotected (river, pond, streams, unprotected wells), (b) protected well outside premises, (c) protected well inside premises, (d) handpumps, (e) piped water outside premises, and (f) piped water inside premises.
8. *Clothing* (a) single pair, (b) three pairs, (c) five pairs, and (d) seven pairs or more, quality of clothing should also be ascertained by observation.
9. *Cattleheads* (a) few goats/sheep, (b) goats/sheep and pair of bullocks, (c) goats, sheep, bullocks and milch cattle, and (d) goats/sheep, bullocks, milch cattle and poultry
10. *Type of fuel used for cooking* (a) fuelwood or cake, (b) coal, (c) kerosene, and (d) cooking gas
11. *Food consumption* (a) expenditure on food plus consumption from own produce, valued at local retail price, and (b) expenditure on non-essential items like fruits, pulses, vegetables, milk products, trendy spices, etc
12. *Health* reach and expenses on (a) local remedies, (b) village medicalman (quack), and (c) district or outside city place specialist
13. *Education* all persons aged 6-18 years have (a) received no education at all, (b) whether one or more persons had left school with incomplete primary education, and (c) either completed primary education or were still at school
14. *Household possessions* 10 possible possessions (a) bicycle, (b) motorcycle, (c) tractor, (d) radio, (e) refrigerator, (f) electric fan, (g) time piece (watch or clock), (h) telephone, (i) sewing machine, and (j) television
15. *Land held* total land owned (unirrigated or irrigated) or rented by the household members

Depending on the local field realities a number of indicators could be included (or excluded) All the indicators should be constructed with reference to local conditions for a specific time frame Small number of indicators would serve the purpose when the target group has considerable socio-economic homogeneity

Other economic indicators

(1) Number of beneficiaries/families moving above/down the poverty-line.
(2) Extent of migration in search of employment (temporary or permanent/within the district or outside the district)
(3) Prevailing wage rates in agriculture and non-farm sector
(4) Extent of indebtedness in cash or kind from all sources
(5) Change in Gram Panchayat incomes
(6) Change in incomes from milk, MFP, etc
(7) Agricultural productivity
(8) Prices and incomes from agricultural produce.
(9) Change in agricultural and non-agricultural land prices
(10) Diversification of product range and skill upgradation of rural artisan

Various strategies can be adopted for assessing the effects of interventions in watershed programme

1 The *first strategy* is to conduct a baseline household survey of pre-project conditions and following up with surveys to measure longitudinal changes in the incomes and economic conditions of the target population during and after the watershed project Same respondents can be re-intervened over a period of time or a fresh sample can be carefully constructed for succeeding survey Such surveys need a battery of highly trained and motivated technical personnel and enumerators

2 The *second strategy* is to conduct a single, cross-sectional household survey at the end of watershed project Objective and subjective questions are asked in the survey regarding changes in respondent incomes and living standards The data collected by this strategy cannot be useful as those collected by baseline and follow-up surveys But, such survey can provide valuable information at a reasonable cost

3 The *third strategy* is to seek the views of local leaders (like sarpanchas), government or non-governmental officials, local experts, etc , through in-depth interviews and/or informal surveys The assessments by these strategies are less accurate and reliable, but cost less time, money and resources These can be biased due to organisational interests and ideological differences

Any of the above mentioned strategies could be adopted for economic evaluation of the target group Moreover, the database could be supplemented by secondary data like agricultural surveys, census, community statistics, etc

Technical and ecological indicators

Numerous technical parameters/indicators are available for evaluating impact of watershed treatment on soil, surface water, groundwater, ecology, etc A battery of indicators are available in various technical manuals

Soil loss

Universal Soil Loss Equation (USLE) It predicts the long-term average soil losses from a specified cropping and management system The equation only predicts the losses from sheet and rill erosion under specified conditions

$$A = R \times K \times L \times S \times C \times P$$

where:

A=Soil loss in tons/ha/year.

R=The rainfall erosivity factor which is the number of rainfall erosion index units for a particular location

K=The soil erodibility factor which compares the actual erosion to that erosion from a clean, tilled, fallowed, uniform slope of 9% and length of 22.13 m.

L=The slope length factor is the ratio of soil loss from the field slope length to that from a 22.13 m length under identical conditions.

S=The slope steepness factor is ratio of soil loss from the field slope gradient to that from 9% slope under otherwise identical conditions.

C=The cover and management factor is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow.

P=The support practice factor is the ratio of the soil loss with a support practice like contouring, strip cropping, or terracing to that with straight row farming up and down the slope.

Runoff

(a) Ogrosky and Mockus formula

$$Q\ \text{peak} = \frac{0\ 0208 \times A \times Qd}{Tp}$$

where:

Qpeak=Peak rate of runoff (cu m/sec)

A=Area (ha)

Qd=Runoff depth (cm)

Tp=Time to peak (hour)

(b) Soil Conservation Service formula

$$Q = \frac{(P - 0.3S)^2}{(P + 0\ 7S)} \text{ for all soil areas except black soil}$$

$$Q = \frac{(P - 0.1S)^2}{(P + 0.9S)} \text{ for black soil areas}$$

where

Q= Actual runoff

P= Rainfall (cm)

S= Potential maximum retention

(c) Rational method

$$Q = \frac{C \times I \times A}{360}$$

where

Q= Peak rate of runoff (in cu m/sec) for the given frequency of rainfall

C= Rational runoff coefficient having values ranging from 0 to 1 depending on watershed conditions
I= Intensity (in mm per hour) for design frequency and for duration equal to time of concentration
A= Area of watershed in hectares

(d) Central Missouri method

$$Q = Qt \times L \times I \times T \times S \times V \times C \times P \times F$$

where:
Q= Peak rate of runoff (cubic ft/sec)
Qt= Peak rate of runoff from a watershed with a specific set of watershed conditions
L= Watershed location factor
I= Topographic factor
S= Watershed shape factor
V= Vegetative cover factor
C= Contour farming factor
P= Surface storage factor
F= Runoff frequency factor

(e) Cooks method

$$Q = P \times R \times F \times S$$

where
Q= Peak runoff for the specific geographic location
P= Peak runoff
R= Geographic rainfall factor
F= Return period factor
S= Shape factor

Sediment test

This can be calculated by using soil turbidity meter An estimation can be made by collecting sample of running water from a *nalla* The particles are allowed to settle down The height of soil/sand particles in the test tube would suggest the extent of sediments in the *nalla* or rivulet Comparisons could be made with previous years data on comparable rainfall days This gives rough estimation but could be effectively done by the community

Waterflow from a stream

(a) *Volumetric method* It is the most simple and accurate method and can be used to measure small discharge flowing through a channel or a pipe Time to fill a known volume of the container is noted with the help of a stop watch Discharge is obtained by dividing the volume of fill by the required time

(b) *Float method* Any object that floats in water but does not obstruct wind or gets carried away by it can be used as a float A dry wood of about 1 cu m size can serve the purpose A straight section of the channel of about 30 m length is selected such that the cross-section is almost uniform through the length The float is allowed to move from the upstream to the downstream end and the time taken to move 30 m distance is measured Several measurements are taken and the average time is noted. The distance divided by the time gives the average surface velocity The surface velocity is always higher than the average stream velocity Therefore, surface velocity is multiplied by a factor of 0.85 to get the average velocity. Similarly, cross-sectional area of the stream is measured at least in three places and the average is taken

$$Q = A \times V$$

where·

Q = Discharge (m^3/s)
A = Cross-sectional area (m^2)
V = Average velocity of flow (m/s)

(c) *Current meter method*: Two types of current meter namely, the cup-type and the propeller-type current meter are used. When the current meter is suspended into a stream, the wheel rotates and the revolutions are recorded on a counter On a calibration chart the graph gives the relationship between the revolutions per minute and the velocity. The average velocity is obtained by taking the average of the velocities at 0 8 m and 0 2 m of the depth from the top In case of a shallow stream, only one reading may be taken at 0 6 m of the depth The cross-sectional area should be divided into a number of sub-sections and velocity readings should be taken in each sub-section If the different areas are A1, A2, A3 An and the corresponding velocities are V1, V2,V3 . Vn, then the total discharge

$$Q = \frac{A1V1+A2V2+A3 \times V3+..+AnVn}{n}$$

Measurement of water table

Observation or bench mark wells should be identified before the start of watershed project Water table readings should be recorded at frequent and regular intervals (say, a fixed date of every month) The simplest method of taking groundwater table is by dipping a measuring tape with chalk marks inside the water in the observation well The water wets the chalk mark on the tape clearly and the difference of this reading from that at the top gives the water table depth A suitable weight (say stone) can be tied at the end of the tape for easy lowering (see Plate 67 a, b). A battery operated electric signaling device can give more precise measurement

Yield test

The equipments required for conducting a yield test are

- A test pumping unit consisting of a submersible pump (with 3-phase motor) and a diesel generating set.
- Measuring device for time, discharge and water level

With the help of pumping set, the water from the well is discharged and the volume of water thus drained out is measured into container along with assessment of time taken Periodic water levels are taken

$$Y = \frac{A \times d \times 6\,25}{T}$$

Plate 67 (a, b) *Water table readings should be recorded at frequent and regular intervals from benchmark wells. Simple SWC techniques could increase the water table to astonishing levels*

where:

Y = Yield capacity of a well (gallons/min)
A = Cross-section of the well
D = Depth of water removed
T = Time for refilling the well on itself

Change in cropped area

Changes in cropped area could be calculated by field to field survey. Change in cropping pattern could easily be determined. Comparisons with baseline data would suggest increase in cropped area due to moisture control (Plate 68).

Plate 68 *Change on cropped area suggests improved productivity.*

Crop productivity test

Test plots should be selected for various soil types and crops from random table Three sub-plots of 10 x10 m area should be selected in a test plot and crop should be cut and the grains/final produce should be weighed Findings of the three readings should be averaged.

$$Q = W \times 100$$

where.

Q = Productivity of crop (kg/ha)
W = Weight of crop produce in 10x10 m sub-plot

$$Qf = \frac{Q1 + Q2 + Q3}{3}$$

Revenue department has various prevalent crop-cutting experiment techniques Almost all *patwaris* (village revenue officers) are well versed with such techniques

Biodiversity index

A survey has to be conducted in a representative manner and in as many compartments as possible. In each compartment quadrates in minimum number and of minimum size have to be laid. And the number of individual herbs, shurbs and trees have to be counted The size of the plots can be 2x2 m for herbs, 5x5 m for shrubs, 10x10 m for trees as per the requirement of site. The species-richness and dominance indices could be calculated using simple formula.

$$D = \text{sigma}\left(\frac{ni}{2}\right)^2$$

where

D = Diversity index

ni = Number of individuals of individual species

n = Total number of individuals

High value of D indicates more diversity and less dominance in an area.

Regeneration byroot stock

On provident protection to heavily degraded forest areas where live root stock exists, regeneration in the form of coppice shoots emerge To take stock these 0 1 ha plots are laid on random basis and species-wise counting done Preferably numerous plots of representative areas are selected About 1200 coppices per ha can be considered as good regeneration (see Plate 69 a, b).

Productivity of grasses

Randomly 5x5 m plots are selected which are representive of the area. Grasses cut are then weighed Dry weights may also be taken.

Soil moisture test

Percentage moisture content on weight basis is

$$Ms = \frac{(Ws - WD) \times 100}{WD}$$

where.

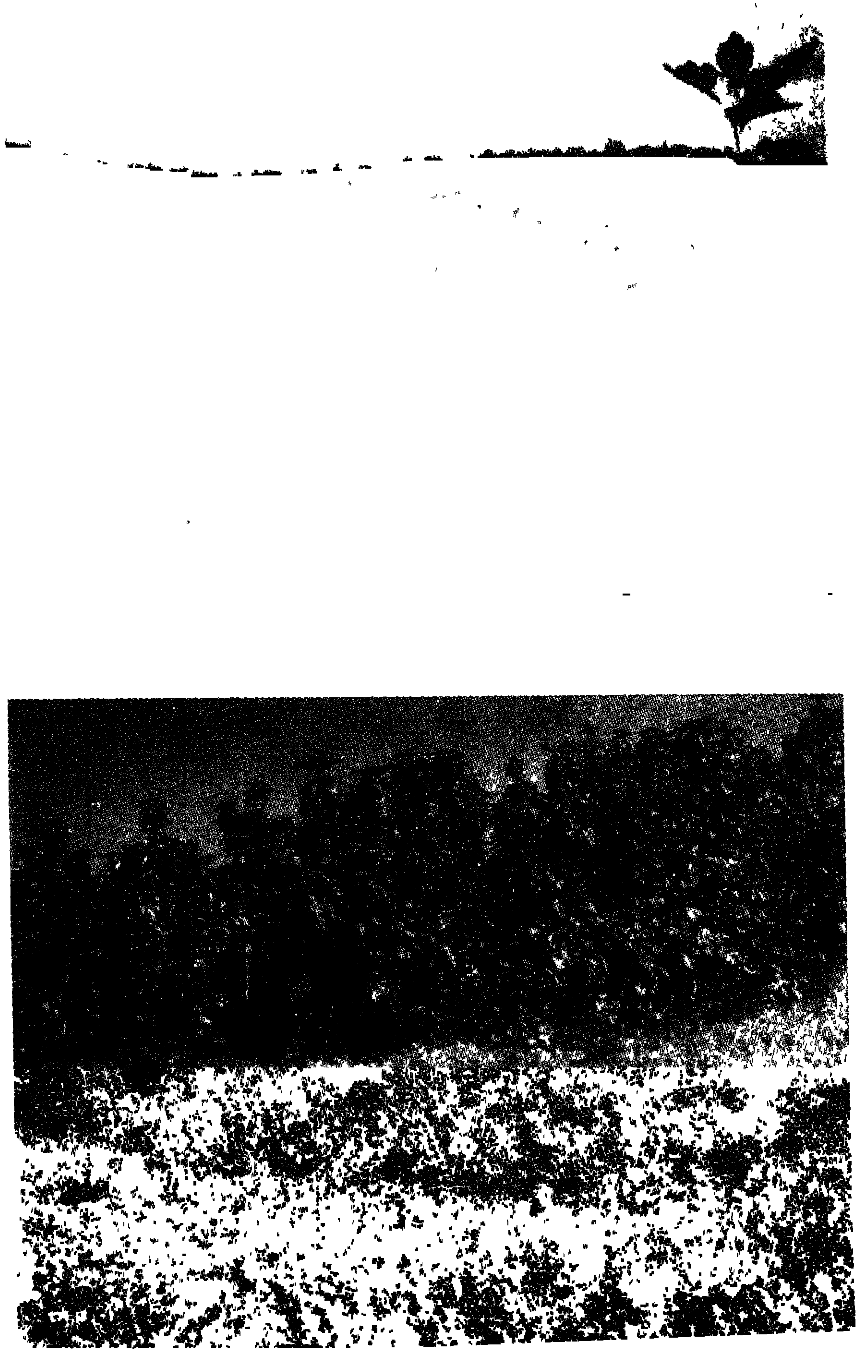
Ms = % moisture content on weight basis

Ww = Weight of wet soil

WD = Weight of oven dry soil

Percentage moisture content on volume basis can be calculated by multiplying Ms by the bulk density of soil. Soil samples from vertical and horizontal dimensions are collected

Plate 69 (a, b) *Successful regeneration of degraded forest resources is a direct indicator of community mobilisation*



in air-tight aluminum boxes known as moisture boxes and their lids are closed The boxes are accurately weighed and after opening their lids they are kept in a thermostatic oven They are dried at a temperature of 105 degree centigrade for a period of about 24 hours After drying, the boxes are weighed again The difference in weight gives the moisture content. This can be expressed either on weight basis or volume basis

Satellite imagery

Remote sensing images of earmarked areas could be compared and analysed with pre-project images This would give non-biased impact assessment in the field about changes in cropped area, water bodies, biomass and wastelands

Other technical indicators

(i) Post project PRA appraisal
(ii) Soil fertility.
(iii) Stability and effectiveness of structures
(iv) Movement of sediment
(v) Fodder and fuelwood availability etc

Other social and behavioural indicators

More specific quantitative indicators may also be used for assessing social, behavioural and organisational impacts of a watershed project

1 change in literacy rate,
2 change in school enrolment, dropouts etc ,
3 level and extent of prohibition,
4 level and extent of controlled grazing,
5 percentage population linked to watershed activities,
6 level of malnutrition in below one year and under five year age groups,
7 gross birth rate of the village,
8 deliveries in institutions or by trained *dais vis-a-vis* unattended deliveries, and
9 infant mortality rate etc

Dozens of such quantifiable indicators could be listed and selected

Criteria and indicators for group performance of SHGs, UGs and WDCs

I *Group characteristics*

- 10-15 members
- Social homogeneity kinship and/or other social ties exist, absence of dependency relations
- Group is not dominated by politically ·economically powerful households or dominant castes
- Poorest and landless households in the hamlet are included in the group
- Proper gender representation is given in the group

II *Group identification and structure*

- Every member knows the objectives and goals of the group

- Every member knows who else is in the group.
- Members are representative of their household.
- Members from geographically dispersed hamlets are included.
- Every member can give the details of all the group activities.
- Every member knows the group's finances.
- Every member is well versed with the processes, procedures and regulations of the group's activities.
- Every member has an equal say in the decision making of the group.

III. *Leadership*·

- Leadership roles change annually/periodically (in a smooth fashion).
- Responsibilities, accountabilities and authorities imparted into leadership takes shape with exposure.
- Leaders have been elected by the group.
- A definitive procedure for the selection/election of leaders based on desired characteristics has been followed.
- Every member has faith and confidence in the leadership.
- Leaders facilitate and do not dominate group discussions and decision-making.
- Leaders represent group interests and uphold group norms

IV. *Group functioning*·

- Group has a set of rules (byelaws) which has been discussed, agreed and adopted
- Group has evolved sanctions for the rule breakers
- Regular group meetings take place with 90-100% attendance
- Group imposes sanctions judiciously and impartially over the law breakers and has moral authority to get it fulfilled.
- Majority of members contribute to group discussion and decision-making
- Unanimous decisions are taken on key issues
- There is full group participation in key activities.
- There are no sub-groups or pressure groups within the group who collide and corroborate without any ideological standing
- The group regularly maintains (a) attendance register, and (b) minutes book

V *No dependence over the PIA*

- Meetings regularly take place in the absence of PIA member or without extraneous coaxing
- Records are maintained without PIA assistance
- Decisions are taken independent of PIA presence.
- Group activities have been initiated independently of the project.
- Group makes use of planning skills (PRA's) on its own
- Group is not dominated by the PIA.
- Group is not financially dependent on the PIAs

VI. *Resource mobilisation*

- Group mobilises specialist skills or services from the government or NGOs
- Group obtains other governmental schemes from outside (but not in response to re-

quests), i.e., group becomes a vehicle for other schemes
- Group members make time available to attend trainings.
- Group has taken help of members from outside of the group for consultation, capacity-building, etc.
- Group can harmonise resource mobilisation and has universal acceptance in the community
- Every member contributes towards financial and human resource mobilisation.
- Every member takes stock of the resources mobilised periodically

VII. *Resource management*

- Benefits reaching the poorest of the poor in the group.
- Equitable usufruct sharing by the group.
- Group has agreed on transparent criteria and priorities for resource management
- Group objectively appraises legitimate needs and demands of members and community
- Group categorises and differentially treats the productive and/or consumptive use of the resources.
- Group agrees for cost for every resource utilised by members or community
- Group attributes responsibility for every commission or omission towards resource management.
- Group ensures participation of every member
- Group agrees on inventorisation and prioritisation of resources
- Group has a definitive policy resource management
- Group provides all logistical support for achieving the objective
- Group ensures necessary skills towards capacity-building for resource management in all members.
- Group realises its rights and duties towards resource management for the group in particular and community at large
- Group has mobilised and used resources for common purposes.

VIII. *Skill acquisition and use*

- Every member has received optional training
- Y% of group members are functionally numerate/literate
- Specialised training needs are put to use
- Group has become self-reliant in all aspects necessary for achieving the objective due to skill acquisition

IX *Distribution of benefits*

- Equitable distribution of benefits are ensured
- The group has provided assistance to members in desperate need or distress
- The need of poorer members are specifically identified in group activities
- Group ensures returns from benefit sharing in common pool for further use

X *Links with external agencies*

- Group is aware of backward and forward linkages
- Group has obtained resources and services from external agencies (governmental or non-governmental)

— Group has inculcated faith, optimism and confidence in external agencies towards the group.

Environment impact assessment of watershed development project

Environment Impact Assessment (EIA) derives from ecology and general systems theory. It emphasises interdependence and linkage. Environmental impact of a watershed development project has to be comprehensive and dependent on social, cultural, economical and political factors. Hence, EIA in a watershed project should be a general impact assessment, involving social, technical and environmental assessment. So, "the integration of the science of environmental analysis with the politics of resource management." (Smith, 1993) holds true for EIA of watershed project.

EIA is a legislative or policy-based concern for possible positive or negative short or long term effects on our total environment, attributable to proposed existing projects (Mitchell and Turkheim, 1977)

It would help to answer three important questions regarding existing watershed development project:

— Has it been technically feasible ?
— Has it been financially viable ?
— Has it been legally permissible ?

It can be broken down into following main steps·

1 Identification of the environmental goals and objectives of the project as related to overall goals and community concerns.
2 Description of the impact and possible alternatives.
3 Description of baseline conditions
4 Description of nature and magnitude of environmental effects.
5. Identification of remedial action and necessary trade offs.

Techniques of EIA

Following are the techniques of EIA.

(a) *Checklists*: Checklists present a specific list of environmental conditions to be investigated. They do not require the establishment of direct cause-effect links to project activities They can be simple checklists, descriptive check lists or scaling/rating checklists These checklists are simple, but they are rigid and are not applicable when even a single parameter has changed

(b) *Interaction matrices* These incorporate a list of project activities on one axis and a checklist of potential impacts on the other The matrix gives a grid diagram and uses symbols or numerical scores in each cell The best known and commonly used interaction matrix is LEOPOLD MATRIX It provides for systematic checking of each development activity against 88 environmental factors (soil, flora, land use, groundwater, etc) It includes 100 possible actions such as plantations, moisture control, social fencing, empowerment of women, prohibition etc. They are also rigid, and sometimes complex and confusing due to duplications, nevertheless they are useful in the absence of sophisticated data and access to complex analytical procedures

(c) *Overlay mapping* These rely on sets of maps of environmental characteristics (physical, social, demographic, ecological, etc) for a project area Different attribute are

Plate 70 *The easiest way to evaluate a watershed project is to judge by the change in living standard of families On completion of watershed project, if even one household resembles the above picture, then there was something grossly wrong with the watershed programme*

compared by superimposing their geographical distribution It is an excellent mean to examine and display visually the spatial nature of impacts Geographical information system (GIS) makes overlay mapping more effective tool

(d) *Networks* Networks are directional diagrams designed to trace in two directions (e g , linkages between project actions and environmental factors) They recognise that a series of impacts may be triggered by any one project action.

(e) *Simulation modelling* This is the application of mathematical and chemical formulae to the modelling of environmental systems Models may describe, explain or predict what happens when one parameter changes in an environmental system It allows for comprehensive testing of the whole system in order to determine both the sensitivity of individual components and the resilience of the system to external shocks

All methods describe impacts rather than evaluate them The decision to choose technique should depend on

— time availability,
— resource availability,
— the nature of alternative to be assessed,
— the role and degree of public participation, and
— administrative concerns etc

Projects with cumulative impacts such as linear additive effects, exponential effects discontinuous effects, etc , should be assessed with advanced form of techniques Use of EIA in watershed project highlights interrelations and linkages with actions and their ecological impacts in a holistic and comprehensive manner (see Plate 70)

List of Abbreviations

CBCS	Community Based Convergence of Services
CPR	Common Property Resources
DDP	Desert Development Programme
DPAP	Drought Prone Area Programme
DRDA	District Rural Development Agency
DWCRA	Development of Women and Children in Rural Areas
EAS	Employment Assurance Scheme
EIA	Environment Impact Assessment
EPA	Entry Point Activity
FYM	Farm Yard Manure
GIS	Geographical Information System
GOI	Government of India
GP	Gram Panchayat
IMSD	Integrated Mission on Sustainable Development
IWDP	Integrated Wasteland Development Programme
JDCP	Jhabua Development Communication Project
JFM	Joint Forest Management
JRY	Jawahar Rojgar Yojna
MDT	Multi-Disciplinary Team
MFP	Minor Forest Produce
MIS	Management information System
NGO	Non-Governmental Organisation
NRSA	National Remote Sensing Agency
NTFP	Non-Timber Forest Produce
NWDPRA	National Watershed Development Programme for Rainfed Areas
PIA	Project Implementing Agency
PLA	Participatory Learning and Action
PPR	Personal Property Resources
PRA	Participatory Rural Appraisal

PRI	Panchayat Raj Institutions
RGMWD	Rajiv Gandhi Mission on Watershed Development
RRA	Rapid Rural Appraisal
SHG	Self-Help Group
SWC	Soil and Water Conservation
UG	User Group
USLE	Universal Soil Loss Equation
WA	Watershed Association
WAC	Watershed Advisory Committee
WDC	Watershed Development Committee
WDP	Watershed Development Plan
ZP	Zilla Panchayat

Annexures

ANNEXURE I *Indicative checklist for information to be colletced*

(a) *Land*		
1	Village area and breakdown by land types	Natural resource mapping
2	Land use and areas	—do—
3	Distribution of irrigated/unirrigated, Fallow/pasture, community/forest/revenue land	—do—
4	Encroached land with direction of slope	—do—
5	Individual land holdings, degree of landlessness non resident landlords	—do—
6	Soil types and its percentage distribution and characteristics	Soil, mapping, pie chart, soil matrix ranking, transact
(b) *Water*		
1	Identification of water bodies (like handpump, wells, check dams, etc)	Natural resource mapping/social mapping
2	Ownership of water bodies	—do—
3	Seasonal variation of water availablity in the water bodies	Seasonality
4	Present use of water bodies (e g , irrigation, drinking, for cattle, wash)	Interview and plotting the information on NR map
(c) *Crops*		
1	Main *kharif, rabi* and summer crops	Interview
2	Varieties of each crops and their characteristics and the reason for preference	Matrix ranking followed by preference ranking
3	Sources of Seeds	Interview/focussed group discussion
4	Seasonality of agriculture operations	Seasonality
5	Trends in productivity of crops	Trend analysis
6	Use of chemical fertilisers, organic manure and the extent of their application	Focussed group discussion
7	Frequency of occurrence of crop pests and seriousness, seasonality, types of pest	Seasonality
8	Local preventive and curative measures	Focussed group discussions

Contd

Contd

9	Methods of pricing and storage	—do—
10	Rates and profits available for crops	—do—
11	Preferences of various crops	Matrix rating followed by preference ranking
(d) *Vegetation*		
1	Different tree species and its uses and there preference	Matrix rating followed by preference ranking
2	Changes in forest cover	Trend analysis
3	Fodder grasses available in the village characteristics	Matrix rating followed by preferance ranking
4	Present use of forest and pasture land	Resource utilisation mapping
5	Existing or past experiences of JFM	Interview
6	Seasonal availability of NTFP and its uses	Seasonality and matrix rating
(e) *Animal*		
1	Major species held	Focussed group discussions, social mapping
2	Ownership pattern	—do—
3	General feeding pattern grazing, stalled feeding, degree of fodder scarcity sufficiency	Seasonality
4	Feed supplementation	Seasonality
5	Main annual diseases and their occurence	Seasonality
(f) *Climate*		
1	Rainfall pattern of last few years	Trend analysis
2	Seasonality/intensity of rainfall for last year	Seasonality
3	Weather aberration	Seasonality
(g) *Socio-economic*		
1	People and livelihood	Interview
2	Settlement pattern (e g , no of hamlets, no of houses)	Social/settlement mapping
3	Demographic profile (e g , no of households, population, etc)	Social/settlement mapping
4	Infrastructure existing in the village (e g , school, temple, bridge, panchyat, etc)	—do—
5	Tribe/dan/caste of village residents	—do—
6	Village history	Time line
7	Change process in the village	Trend matrix
8	Main occupation and sources of income	Informal discussion
9	Income and expenditure pattern of different classes	Pie chart
10	Proportion of households indent, reasons for indebtedness, sources of credit, rates of interest and method of repayment	Pie chart, focussed group discussion Seasonality
11	Proportion of householdes migrate class/group migrate, amount earned seasonality of migrate	Pie chart, seasonality, FGD
12	Leadership (traditional and present)	Informal discussion
13	Village institutions (present and past)	ID, trend analysis
14	Employment opportunities besides agriculture available in the village	ID
15	Village dynamics (inter-class/group/class relationship/power structure etc)	ID
16	External forces operating in the village	Venn (*chapati*) diagram

ANNEXURE II *Grain-banks ensuring food security*

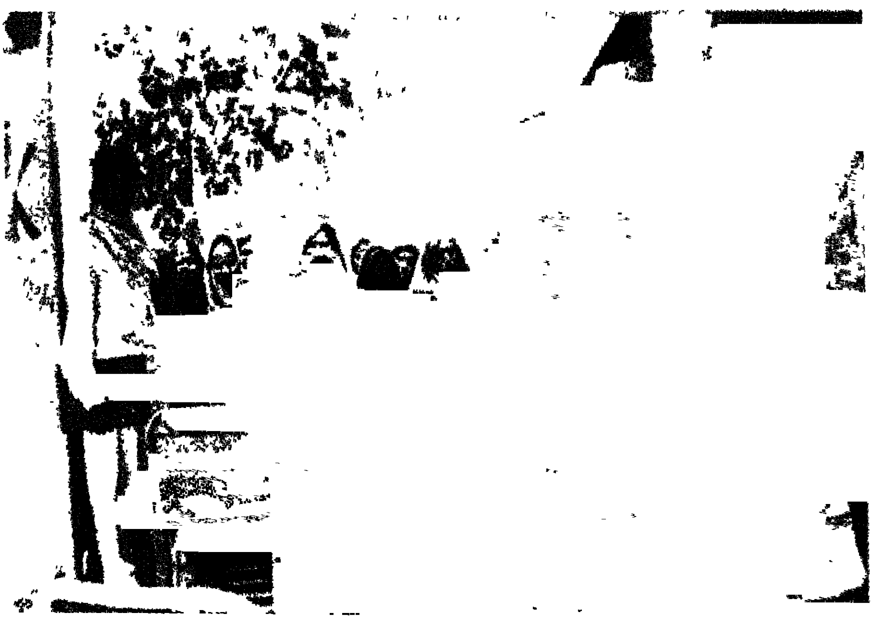
(1) Objectives

- To establish grain-bank in the village.
- To provide a safeguard against fall in nutrition standards of people and to provide food security network in the village
- To check deaths of village community due to starvation, malnutrition, etc., and motivating the people to shoulder the responsibility of running the grain-bank in an efficient manner.
- To reduce the dependence of tribals on money lenders for foodgrains in food-scarcity months.
- To assist in reduction of crime rates
- To inculcate the habit of self-help with a view to take care of their basic requirement in times of need.

(2) Funding source

Funds available to the PIA under entry point activity or community mobilisation could be utilised in establishing grain-banks in watershed areas. Voluntary contributions and donations, which are collected and deposited in *Gram Kosh* could be used for the same. Per grain-bank expenditure of Rs. 1500 on purchase of weights and balance, Rs. 1500 on storage, Rs. 500 on transportation is allowed. About 25 quintals of wheat or maize (depending on local preferences) should be stored in the grain-bank. An outlay of Rs. 12,500 is kept

Plate 71 *Grain-bank*



for such purchases. As far as possible, storage should be done at voluntary place provided by the community and the foodgrains should be lifted from State Civil Supplies Corporation depots.

(3) Modalities (guidelines)

(a) All the families residing in all the hamlets of the concerned village shall be members of the grain-bank

(b) Proposal to initiate grainbank in the watershed village should be initiated by the Gram Panchayat and WDC.

(c) The grain-bank should ideally be located at the centre point of the village. A safe building for storage should ideally be selected by the WDC. All the members in the village should be communicated about the establishment of the grain-bank through different forums, using various means

(d) Every household shall have an entitlement of 50 kg foodgrains in two instalments, especially in non-agricultural season WDC shall be authorised to increase this limit to 100 kg, in special cases.

(e) The WA will select a working committee to run the grain-bank The tenure of the working committee shall be for three years. The working committee shall be headed by the traditional headman of the village The volunteer of the WDC shall be ex-officio member secretary of the committee

(f) The working committee should consists of upto seven members, depending upon the strength of the membership of the grain-bank At least 50% seats shall be reserved for women

(g) The working committee should decide modalities to run the grain-bank in consultation with WDC Loan of foodgrains per family, interest rates, recovery period, record keeping, etc., should be evolved

(h) The suggested recovery period and interest rates shall be follows·
   — if the recovery is in 3 months= 5% interest rate
   — if the recovery is in 3-6 months= 10% interest rate
   — if the recovery is not done within 6 months=15% interest rate+fine to be imposed by working committee.

(i) The membership of the defaulter family should be abstained till the time, the interest and fine is deposited and the WDC has re-established the membership

(j) The type of grain to be repaid should be same as the type of grain loaned

(k) The group shall use 5 kg sunnhemp seeds for 25 quintals grains or *Neem* leaves as pesticide for storage of foodgrains

(l) Every member should have a small passbook for the grain-bank The entries of loan and recovery should be made in them.

(m) Group shall do regular meeting after every 15 days and discuss about progress of grain-bank.

(n) The working committee shall ensure the maintenance of loan register and recovery register by volunteer.

(4) Monitoring

(a) Every PIA shall appoint one MDT member to regularly inspect the grain-bank in al-

loted village.
(b) Weekly Wednesday meetings of WDC shall necessarily have grain-bank as their agenda.
(c) The progress of the scheme be presented in all Gram Sabhas and WA meetings.

(5) Results

The scheme was launched on pilot basis in 1995 in 17 villages. The performance of last two years encouraged DRDA to adopt the strategy in all the villages under Integrated Watershed Development Programme. Presently, there are 314 grain-banks functioning very efficiently in watershed areas by the community itself. In last season, 12,363 families took loan from the grainbank. The repayment was 97.8%. Rest 2.2% could not repay due to migration or failure of crops. The grainbanks have ensured food security to poverty stricken household in Jhabua.

Indebtedness in tribals has been a crucial problem in ST areas. Forced migration occurs mostly due to perpetual indebtedness of tribal families. In a survey conducted few years back, 88% of tribal families in Jhabua district were found indebted In Jhabua consumption loans are received from moneylenders and institutional financial set up is very rigid to cater to such loans. Women in tribal areas are economy earners for their families. Even after that they are dependent on their male counterparts for managing households. To achieve the dual impact of empowerment of the women and emancipating from indebtedness, women credit and thrift groups (Bairani Kuladi) have been created in Jhabua district.

Bairani Kuldi, which means 'women saving banks' in Bhili, is formed and managed by tribal women. In every Bairani Kuldi 10 to 15 women are selected by the community or the households and they save at least Re 1 per woman per day In weekly meetings these savings are deposited in their accounts which is normally opened with commercial, cooperative or rural banks in their vicinity. The process of weekly meeting ensures group mobilisation and unity. Over a period of six months, this process is continued on a regular basis. Only after six months such women groups are linked with DWCRA scheme. When the group has achieved unity in its objective and a substantial amount is saved by such women groups, then Rs 25,200 is given from DWCRA scheme This amount, along with their savings, is envisaged for crediting and thrifting. The group decides the leader and differential interest rates for the members from the group and for the members outside the group. Any member from the group or outside the group can apply for a loan (usually small consumption or production loans), the the group in its meeting unanimously decides about the sanction of the loan and the amount of the loan Usually three to six months are given to the loanee to deposite the amount with due interest.

Loan from Bairani Kuldi is usually given for education, health, agricultural inputs, land development, minor irrigation, small trading activities, repayment of loan to the money lender, marriage and other social and religious ceremonies, etc. Bairani Kuldi, also called as 'women banks', may start production activities when enough money is available and a level of confidence is achieved within the group.

These groups were started in 1994 in watershed areas of Jhabua district. Now, certain new linkages have been provided to give incentive to the women·
(a) DWCRA Scheme (under which Rs. 25,200 is paid for crediting and thrifting to the group)

(b) Watershed Self-Help Groups (SHGs) Revolving Fund (under which Rs. 50,000 is made available as revolving fund to various groups operating within the village/watershed).

(c) SHG Scheme of NABARD (under which four times of the amount saved and collected in the name of women group may be taken on soft interests from commercial banks for productive purposes).

(d) Training and backward-forward linkages of raw material and buy-back guarantee are also provided to these groups for certain productive activities like Agarbatti making

Presently, there are 1073 Bairani Kuldis (Women Credit and Thrift Groups) formed and operating in Jhabua district Rs. 1 06 crore has been given to 504 groups as revolving fund under DWCRA scheme. Overall 1073 Bairani Kuldis have collected around Rs 2.45 crores in their accounts.

A proposal for DWCRA assistance to 500 such Bairani Kuldis (women banks) was sent by the district administration The Government of India had sanctioned Rs. 126 lakhs in the year 1996-97 on 50:50 basis. The State Government has given its share of Rs. 12,600 per group, i e., Rs. 63 lakhs but the Government of India has not allocated its share of Rs 63 lakh under DWCRA. This amount should be released to the District Collector/DRDA, Jhabua at the earliest. Since then 500 new Bairani Kuldis have come into existence. It would be proper to sanction Rs. 126 lakhs for these groups also by Govemment of India on 50 50 basis

ANNEXURE III *Use of plant products for pest control*

1 Farmers can choose the treatment depending on the availability of the plant products in their area It is also important to maintain the control plot so that this can be compared with the treated plot.

2' The treatment can begin after identifying the pest or disease The first treatment can be taken up when there is minimal infestation

3. The size of the treatment is left to the farmer and this could vary. If the experiments are done on tree crops, 5-10 trees can be taken up for a single treatment.

4. The insects can be counted wherever it is possible. If it is a bigger area the intensity of the disease could be graded such as 0, 1, 3, 5, etc. Count the insects
   (a) before spraying
   (b) one week after spraying
   (c) two weeks after spraying
   Take the 15th day counting as before spraying counting for second round of treatment, if the second round of spraying has to start immediately

5 For disease, the counting should be done
   (a) before spraying
   (b) three weeks after spraying
   (c) six weeks after spraying
   Spraying should also preferable be done at the time of sunset

Suggested treatments for finding out efficacy of bio-pesticides

S.No	*Bio-pesticides*	*Concentrations*	*Quantity of bio-fertilisers required for 1 acre (200 litre of spray fluid)*	*Suggested pests and disease for which it is effective*
1	*Neem* kernal (aqueous-solution)	3%	6 kg of kernal powder	Paddy leaf folder, sucking pests of cotton, groundnut leaf miner, citrus leaf miner, *Prodenia*, Red hairy caterpillar, paddy *Tungro* virus, paddy sheath rot disease, citrus canker
		5%	10 kg of kernal powder	
2	*Neem* oil	1%	2 litre of *neem* oil	-do-
		2%	4 litre of *neem* oil	-do-
		3%	6 litre of *neem* oil	-do-
3	*Neem* oil + pungam oil	2%	1 litre of *neem* oil + 1 litre of pungam oil	-do-
4	*Neem* kernal powder (basal application)	100 kgs per acre	100 kg of kernal powder for cotton stem weevil	-do-
5	Cow urine + *neem* kernal (aqueous solution)	2%	4 litre of cow urine + 5 kg of *neem* kernal	-do-
		5%	10 litre of cow urine + 6 kg of *neem* kernal powder	-do-
6	*Neem* (leaf extract)	5%	10 kg of *neem* leaves	-do-
		10%	20 kg of *neem* leaves	-do-
7	Garlic + kerosene (solution spray)	0.5%	1 kg of garlic	*Heliothis armigera*, sucking pests of pomegranate, grapes, etc
		1.0%	2 kg of garlic	
		1.5%	3 kg of garlic + 100 ml kerosene	
8	Custard apple (seed extract)	1%	2 kg of kernal powder	Paddy fulgarid, sucking pests of all crops, grass-hopper, pumpkin beetles
		2%	6 kg of kernal powder	
		5%	10 kg of kernal powder	
9	Cow urine + tobacco wastes	3%	6 kg of wastes+2 lit urine	Citrus leaf miner, citrus scales, chilli thrips, chilli white mite
		5%	10 kg of wastes+ 2 lit urine	
10	Palmarosa (oil wastes)	0.2%	400 gm of oil waste	Storage pests, paddy pests
		0.3%	600 gm of oil waste	
		0.55%	1000 gm of oil waste	
11	Granite powder (basal application)+ *neem* kernal (aqueous spray)	—	50 kg of Granite powder + 3% *Neem* kernal powder spray	Pests/disease affecting horticultural species
12	Cowdung (solution) +*Prosopis* (leaf extract) + 200 gm of *Azospirullum* (*Azospirullum* can be applied to soil by mixing with FYM)	—	10 kg of cowdung 10 kg of *prosopis* leaves 200 gm of *Azospirullum*	Tomato spotted wilt, onion leaf blight

Contd

Contd

13	Chilli powder (solution)	0 5%	1 kg of chilli powder	Aphids, ants, cutworms, virus diseases, leaf caterpillares
		1 0%	2 kg of chilli powder	
		1 5%	3 kg of chilli powder	
14	Aqueous solution of *Melia azadirachta* kernals	3%	6 kg of kernal powder	Sucking pests and leaf caterpillars
		5%	10 kg of kernal powder	
15	Turmeric rhizome powder (solution)	2%	4 kg of powder	Aphids and bacterial and fungal diseases
		3%	6 kg of powder	
		5%	10 kg of powder	
16	Turmeric Powder+Ash (1 4)	10 kg	2 kg of powder 8 kg of ash	Aphids, powdery mildew
17	*Tulsi* (leaf extract)	5%	10 kg of leaves	Bacterial and fungal diseases
18	Papaya (leaf extract)	5%	10 kg of leaves and pods	Bacterial and fungal diseases and nematodes
		10%	20 kg of leaves and pods	
19	*Prosopis juliflora* (leaf extract)	10%	20 kg of leaves	Paddy sheathrot disease
20	*Ipomoea fistulosa* ((leaf extract)	5%	10 kg of leaves	-do-
		10%	20 kg of leaves	
21	*Aloe vera*(pulp extract)	3%	6 kg of flesh (pulp)	-do-
		5%	10 kg of flesh (pulp)	
22	*Mahuva* oil	2%	4 litre of oil	-do-
		3%	6 litre of oil	
23	Pungam oil	2%	4 litre of oil	Storage insect pests
		3%	6 litre of oil	
24	Tobacco waste solution	3%	6 kg of wastes	Citrus leaf miner, citrus scales, chilli thrips, chilli white mite
		5%	10 kg of wastes	

Notes

(a) The kernal powder is normally soaked overnight in water

(b) For the preparation of leaf extracts fresh leaves should be powdered and the extract should be taken out This is mixed in water and sprayed Alternately it could be boiled in water, filtered and used

(c) Tobacco waste is soaked in water for five days before spraying

(d) For control of termites and nematodes the application of the plant products should be on the soil

(e) While making the garlic extract, the garlic should be soaked in kerosene overnight

(f) 200 gm of *Khadi* soap or teepol is mixed while spraying This increases the adhering property of the product

ANNEXURE IV *Weed management*

Weeds can be easily avoided or removed only if timely operations are taken up. The tillage with pre-monsoon rains encourage weeds to germinate and emerge on to the surface. A simple blading will remove/eliminate most of these weeds. Once the crop is sown (it is best done by using seed-cum-fertiliser drills) in lines, the weeds that emerge with the crop can be removed timely.

As a rule of thumb, the first weeding has to be done within three weeks of sowing through intercultural operations with a subsequent rain after sowing received within 18-25 days. If the holdings are large and there is delay, the interculturing may be shifted from use of blade harrows which have a better cutting edge. As the crop grows, it develops a canopy to cover the whole ground. This is the time upto which weeding has to be done or seeds need to be taken care of. Once the full canopy is developed the weeds would be weak, causing no damage to the crop. This period upto which weed-free fields would be beneficial to obtain higher yields has been worked out:

Crop	*Period upto which the crop need be weed-free*
Bajra	4 wks
Castor	9 wks
Cotton	8 wks
Greengram	4 wks
Groundnut	7 wks
Maize	6 wks
Ragi	5 wks
Rice	6 wks
Sesame	6 wks
Sorghum	5 wks
Sunflower	4 wks

There are certain pernicious weeds that need separate consideration. Some of the weeds that can be controlled through biological means are listed below:

Pernicious weed	*Biological agent (insects)*
Opuntia dillenii (prickly pear)	*Dactylopius opunitiae* (cockerell)
Opuntia vulgaris (drooping prickly pear)	*Dactylopius celonicus* (green)
Eichhornia crassipes (water hyacinth)	*Neochetina bruchii N eichhorniae*
Salvania molesta (water fern)	*Cystobagous sarviniae*

Following promising bio-agents are in final testing:

Nutsedge (*Cyperus rotundus)*	Stem boring weevil *(Bacteria minima)* Rhizome and stem boring weevil *(Athesapacuta cyperi)*
Broomrape *(Orabanche Sp)*	*Phytomyza orabanchiae*
Cuscuta Sp	*Melanagromyza Sp*
Loranthes Sp	*Dalias hyparete*

It has been argued that unlike pesticides, herbicides are not harmful to human beings.

Crop	*Herbicides*	*Dosage (kg/ha)*	*Method of application*
Sorghum	Atrazine	1 0-2 0	Post-emergence
Pearl millet	Atrazine	0 5-1 0	Post-emergence
Upland rice	Butachlor	2 0-4 0	Pre-emergence
	Alachlor	2 0-2 5	Pre-emergence
	Proponil	2 7-3 5	Post-emergence
Maize	Atrazine	1 0-2 0	Pre-emergence
	Samizine	2 0	Pre-emergence
	Alachlor	2 0	Pre-emergence
Redgram	Alachlor	2 0-3 0	Pre-emergence
Soybean	Trifluralin	1 0	Pre-plant incorporated
Groundnut	Alachlor	2 0	Pre-emergence
	Nitrogen	1 0-2 0	Pre-emergence
Castor	Trifluralin	1 0	Pre-plant incorporated
Clusterbean	Trifluralin	1 0	Pre-plant incorporated
	Alachlor	1 5	Pre-emergence
Mungbean	Trifluralin	1 0	Pre-plant incorporated
Blackgram	Alachlor	2 0	Pre-emergence

It should be noted that per se these chemicals would be less effective than when coupled with mechanical measures Thus high-cost input like herbicide should be more efficiently used by band placement, wherever possible and coupling with interculture operations

ANNEXURE V *Vermicompost*

The vermicompost consists of earthworm casts, indigested organic matter, eggs (cocoons) and young ones of earthworms It contains micro-organisms ejected from the gut of earthworms which are useful in further decomposition of the organic matter in the casts. The vermicompost, on ripening, is a good source of humus It also contains substances like hormones, auxins, vitamin B_{12} and other growth promoting compounds and antibiotics like actinomycetes.

The first requirement for preparing vermicompost is a shed because these earthworms have to be protected from the sun and the heavy rain The earthworms can tolerate temperatures 0^0-40^0C, but for the best results in their growth rate they should be kept at 25^0-30^0 C, so that their activity in breeding themselves and producing compost is maximum. The size of the shed varies, depending on the availability of waste materials One shed can accommodate two beds and a walking or working space in between, the width of the bed should be limited to 1 2 m to permit easy access to the centre during harvesting

The worms are fed on different waste materials having a network of inter- relationships. All these materials go into the food of the earthworms. The heap length can be increased, depending on the availability of wastes even upto 30 m. The width and height should not exceed 1.2 m and 0.6 m respectively.

The second requirement is a selection of earthworm species. The earthworms can be divided into two main groups. The deep burrowing group, e.g., *Pheretima elongata*, the intermediate group, e.g., *Eisenia foetida* The earthworms from any of these two groups can be used to make vermicompost. They have their merits and demerits, however the worms of the species *Eisenia foetida* are generally preferred for vermicompost making as they are basically dung feeders and prefer organic matter such as plant residues in semi-decomposed state, animal wastes, FYM, sewage sludge, kitchen garbage, etc., as their food. They grow rapidly and multiply prodigiously and are the best converters of organic wastes into valuable organic fertiliser-vermicompost.

When vermicompost prepared by using these worms is used in field application, they must be supplied with sufficient organic food materials and a minimum amount of moisture in the soil during dry season to keep them active and alive. Whereas, the deep burrowing native worms are better equipped to adjust, i.e., to hibernate, during dry spell of the year. However, if the required food and moisture conditions are provided, the red worm or manure worm (*Eisenia foetida*) will improve the soil as good as the native deep burrowing worms or even better. The vermicompost prepared by using these worms will add plant available nutrients and growth factors through the castings as well as through the worms themselves. Following steps should be taken care of:

(1) Wet the ground on which wastes are to be placed by sprinkling water.

(2) A layer (5 cm thick), consisting of coarse bedding material like coconut fibres, sugarcane trash, grasses, or dry banana leaves cut to smaller size should be placed on wet ground This bedding place serves as a home for the earthworms during lean days and during compost preparation, i e , removal of compost from the beds.

(3) The second layer of about 7.5 cm thickness is laid on the bedding material layer It consists of partially digested dry cowdung or the dried sludge from the biogas plant. This second layer serves to prevent excessive heat being generated in the second and upper layer by providing aeration. This second layer, being partially digested, also serves as food for earthworms. These two layers, thus, have a thickness of 10-12.5 cm from the ground. The earthworms may settle here under temporary adverse conditions, like excessive heat in the afternoon, or a temporary water shortage occurring for short periods. The lowest areas not exposed to sun usually contain enough moisture although the upper layers get dry.

(4) Earthworms are then lightly placed on the second layer in a uniformly distributed fashion on the surface These earthworms should be of the right species. To start with about 2000 earthworms would be spread evenly on the second layer. This inoculation of the earthworms should be carried out carefully, so as, not to crush or damage the earthworms Preceding the inoculation, the second layer should be sprinkled with water mixed preferably with cow urine, keeping the surface of the second layer slightly moist It should not be too dry or too wet

(5) The third earthworm layer would not have a separate clear-cut existence, because the earthworms would quickly get down into the second layer, since they do not like to be

exposed to the atmospheric light and heat. Within minutes of placement; the second and third layers will merge. A fourth layer is next placed on the merged second and third layers. This consists of cowdung mixed with crushed biomass from tree leaves, household and agricultural wastes. These should first be mixed thoroughly outside the bed and then spread uniformly on the second-third layer. This layer could be 10-30 cm high

(6) On this is placed a layer of fresh cowdung mixed with shredded green biomass, or other types of bio-degradable waste materials This layer is also about 10-12.5 cm high.

(7) On top of this layer, a long gunny bag cloth 1.2 m wide is spread to cover the entire heap.

(8) The sides of the heap could preferable be enclosed in bio-degradable fresh material whose particle size is reduced. This would protect the worms from, intruders from outside getting into the heap Also any stray earthworms moving outside the heap could be trapped and returned to the heap.

(9) Water should be sprinkled regularly on the top of the gunny bag spread. The quantity should be determined by the farmer, who should examine the wetness from time to time depending on the season

(10) Measure the temperature and the pH of the compost after one week. Also examine the colour which should become black Do this every week

(11) The first heap would be fully composted after 4-6 weeks The colour would be black, and the material becomes very light in weight The worms usually come up after devouring all the materials from the bottom Where there are a large number of worms sticking to the gunny bag cloth, the compost is ready

(12) The ready compost is then collected in conical heaps on the surface of the pile The stray worms which exist in this heap will go down to their bed in 2-3 hours because they are exposed to outside light. Collect the top portions of the pile as compost to be stored in a shed.

(13) All the earthworms are collected at the bottom and load the bed again as in steps 1 to 12.

Watering could be twice a day in summer, once in winter, and in the rainy season, the wetness should be checked before watering Precautions should be taken to avoid either water stagnation or water flow through and across the heap If there is a heavy rain period, it is advisable to cover the shed with plastic cloth and also dig trenches on all sides of the heap for effecting water runoff

ANNEXURE VI *Trees and plants with medicinal properties*

1 *Acacia catechu (Catechu, Khair)* The dried juice extracted from the trunk known as 'Katha' is used as an constipative agent. It is also an astringent. Bark decoction with ginger extract is used as mouth wash to cure toothache

2 *Acacia ferruginea (Shami)*: Its bark is an astringent, useful for treating cough and asthama

3. *Acacia nilotica (Babul or Kikar)*: Tender leaves of this tree are used for diarrhoea and premature ejaculation. The bark decoction is used as a washing solution for quick healing while treating prolapsis of rectum among infants. Decoction of tender sprouts is used to prevent threatened abortion. Extract of the twigs of this species and A. modesta are used to treat dysentry, leprosy, oral wounds, trachoma, toothache and veneral diseases.
4. *Acacia pinnata*: The stem, twig and roots are used for treating aphrodisiac and as an evacuant.
5. *Acacia species*: Tyramine and tryptamine extracted from these species are used as vasoprossor agents for treating heart diseases.
6. *Adhatoda vasica (Adhatoda or Malbar nut)*: The leaves of this plant can be used to treat lung diseases and act as an expectorant for expellation of phlegm. This germicidal and antiseptic agent is known for its blood purifying properties. The leaves also help to control ring worms and bleeding of nose.
7. *Aegle marmaloes (Bael)*: Commonly known as 'Bel' has many medicinal uses. The fruit pulp is used for cold drink, to reduce heat exhaustion and to cure chronic diarrhoea, dysentery and amoebic dysentery and the diseases of intestine and liver The leaf has antibiotic property and the paste is used for curing sore and inflamed eyes. Leaf is also useful for treating cough, rheumatism and diabetes The twigs are used to treat dysentry.
8. *Agave sisalana*: This is used for extracting Hecogenin hormone.
9. *Albizia lebbeck (Siris)*: Its bark decoction is used as a mouth wash to relieve toothache. Bark is also used to treat bronchitis, leprosy, paralysis, gum inflammation. The seed snuff is helpful to treat cold. Seed powder is consumed to control spermatorrhoea and premature ejaculation.
10. *Aloe barbadensis (Barbados alae or 'Ghikanvar')*. This plant is also known as A. vera. The mucilaginous pith is used for treating chronic cough, asthma and lumbago Large dose is given as purgative. Dried juice is given in constipation. Root is given in colic.
11. *Alstonia scholaris (Devil's tree)*· This dried bark of this tree is useful to treat chronic diarrhoea, dysentry, malarial fever and skin disease. Milky juice is applied to ulcers.
12. *Anthocephalus cadamba (Kadamba)*: Its bark is used as a febrifuge, tonic and astringent. The fruit juice is given to treat gastric irritability and thirst during fever Decoction of the bark is used to treat fever.
13. *Atropa acuminata (Belladonna)*: It is a herb and the dried leaves and shoot tips collected at the time of flowering are used as strong antispasmodic in intestinal colic and other spasmodic indications. Leaves and roots are also useful for asthma and whooping cough Leaf paste is useful for external application on rheumatism, neuralgia and inflammations
14. *Azadirachta indica (Neem)*: It is an important medicinal tree. Its bark is an astringent and antiperiodic, useful to treat fevers and skin diseases. The paste is used to clean wounds. Its oil and leaves are also used as antiseptic and the root bark decoction is used to treat antihelmenthic problems of children Flower and leaf paste is applied as poultice to relieve nervous headache. Seeds are used in treating rheumatism The twigs are used throughout Asia as antipyretic and antiseptic for treating skin diseases

15. *Bauhinia variegata ('Kachnar' or Mountain ebony)*: The dried flower buds are useful to treat diarrhoea and piles. The flowers are mixed with sugar to act as laxitive The bark decoction is used to treat ulcers and skin diseases. The bark of other species B perpurea is an astringent and the root is a carminative. Seed of *B tomentosa* is aphrodisiac
16. *Bixa arellana (Annatto)*· The fruits are astringent and purgative Root-bark is antiperiodic, febrifage, antipyretic and a good remedy for gonorrhoea. Leaves are used in jaundice and snake-bite
17. *Bombax ceiba (Silk cotton)* The dried root powder is aphrodisiac and the bark is used to treat abscesses. Its gum has hacmostatic property and is also used to promote sexual drive and performance.
18. *Boswellia serrata (Salai)*. The gum is used for disphorietic, diuretic astringent, emmenagogue, in rheumatism, nerve and skin diseases.
19. *Butea monosperma (Palas, Dhak or Flame of the Forest)* The leaves are used to treat boils, pimples, tumors and haemorrhoids A diluted bark decoction is useful to treat catarrh and cough Its leaves, shoot, gum and bark are useful to treat spermatorrhoea, premature ejaculation and leucorrhoea The flowers reduce the inflammation. The flower and leaves are used as aphrodisiac The flower paste is applied for orchitis (swelling of testicles). The seeds are used for treating fever, malaria, round worms and tape worms The tapping of tree trunk yields a red colour gum known as Kino, containing kinotannic acid. It is an astringent, useful for treating diarrhoea
20 *Caesalpinia crista (Fever nut, Molucca bean or 'Karanjum')* The leaves are used for treating malarial fever The kernel is antiperiodic, antipyretic, febrifuge and helpful to purify blood, clean intestinal parasites and the seeds roasted in shell are used to cure asthma, flatulence and scabies.
21. *Caesalpinia gilliesii(Bird of paradise)* This ornamental shrub contains 'cesalin' C nuga leaf powder is used as an uterine tonic following child birth Its roots are used for treating calculi in the bladder
22 *Calophyllum inophyllum (Indian laurel or 'Surpan')* Its bark, seeds, oil and leaves are used as medicine. Oil is used for rheumatism gum exuding from its wounded bark is used for treating wounds and ulcers.
23 *Calotropis gigantea (Madar-purple flowers) and C procera (Akund-flowers)*: The root bark is used for skin disease and flowers are used to treat cough, asthma and loss of appetite The other parts of this plant also have medicinal properties.
24 *Carica papaya (Papaya)* Papain is used as a meat tenderiser. Pepsin which is present in the ripe and unripe fruits helps in digestion and is also used to cure inflammation of liver and spleen The sap is used to control ring warms and intestinal parasites, including amoeba
25 *Careya arborea* Bark and fruit are astringent Juice of bark is demulcent
26 *Cassia fistula (Amaltas)* The pulp of the pods is a laxative, but generally administered with senna The flowers can be used as laxative and for cough relief It is also a suitable remedy for diphtheria Root is useful to treat fever and heart diseases
27 *Cassia species*: *Cassia absus* ('chaksu') and *C sophera* ('Kasaundi') bark and seed extracts are used as antihelmintics Roots of *C alata* ('Dadmurdan'), bark of *C javanica* (jawa cassia), dried leaves of *C angustifolia* (Indian senna), leaflets of *C*

marilandica are used as purgative. Leaves of *C. sophora*, *C. reticulata* and *C tora* are used to treat skin diseases.

28. *Cedrus deodara (Devdar)*: The oleo-resin collected from the wood is applied to ulcers and skin diseases. The wood is a carminative, while the bark is used to treat fever, diarrhoea and dysentry.
29. *Cinchona species*: *C calisaya* (grown in Nilgiris and Sikkim), *C ledgeriana* (most popular species in Bengal, Assam and South India) and *C officinalis* (Nilgiri) are found in India Its bark yields quinine and other effective drugs, useful to treat malarial fevers, bacterial infections, pneumonia, amoebic dysentery, eye infection and rheumatic pains. Quinine is not administered to pregnanat women and people with heart ailments.
30. *Cinnamomum tamala (Tamal or 'Tejpat')*: Its bark, leaves and oil are used in medicine. Oil is also used for toothache.
31. *Citrus aurantifolia (Lime)*: The stem is used to treat dysentry, fever, headache, opthalmia, oral infections, vermifuge and vomiting. The docoction of leaf is used for candida mouth infection.
32. *Dalbergia latifolia (Rosewood)*· The sapwood gum is used for treating wounds.
33. *Dalbergia sissoo (Shishum)*: The wood extract is used for blood purification, control of scabies, ring worm and leucoderma. The leaf paste is used to cure saddle sore and snake bites.

34 *Dalbergia stipulacea*: Bark and roots are used for promoting menstruation and to induce abortion.

35 *Datura metel (Datur)*: The leaves are used in asthma and whooping cough. The seeds are used as an astringent for digestive disorders and skin diseases. Fresh juice from leaves is applied externally in rheumatic pains and inflammation caused from mumps. Datura smoke released while burning fresh leaves gives relief during mumps This plant is the source of 'scopolamine', used for dilating the eyeas.

36 *Derris indica (Pongamia)*: The twigs are used for treating skin diseases in Sri Lanka

37. *Embilica officinalis (Amla)*: The fruits, rich in Vitamin C, are a liver tonic useful to control hair fall and premature graying. It is also used as a cure for several physical and mental disorders The dried fruits help in healing bone fractures and treating acidity, cough and haemorrhage. The leaf extract is used as a cure for burning eyes

38 *Eucalyptus macrorhyncha*: It contains a bioflavonoid called 'Rutin', having medicinal properties Seeds cure asthma and stomach disorders.

39. *Eupatorium truokuberve (Joe-pye weed or Ayapana)*· Leaves have hypoglycemic activities and also used as cordiac stimulant and tonic.
40. *Euphorbia neerifolia (Milk hedge, Thohar)*· The milky sap is a purgative and also helpful to treat syphilis, rheumatism, leprosy and chronic cough

41 *Feronia limonia (Wood apple, kawat)*: The unripe fruit is used to treat dysentry. A medicated oil is prepared for body massage by using the flowers, roots, leaves, bark and fruit of this tree.

42 *Ferula assafoetida (Asafoetida, Hing)* The resin of this plant is used to treat flatulence and in formulation of digestive powder It is a stimulant for respiratory and nervous system. It is also an antidote for opium toxicity (1.1 ratio)

43 *Ficus benghalensis (Banyan tree)*. The leaf sap is used for treating cracking of heels in

winter(kibes), briuses and for treating rheumatism. Tender aerial roots are ground in water and administered for preventing vomiting. The extract of different parts of this plant are also used for curing spermatorrhoea, premature ejaculation and diabetes

44. *Ficus carica (Fig)*: The fruit serves as a laxative and expectorant. It is used to cure inflammation of the spleen and hastens the appearance of rash in case of chicken pox and small pox.
45. *Ficus grabrata and Ficus laurifolia (Fig)* The latex contains a proteolytic enzyme called Ficin which digests living Ascaris and Trichuris worms while non-toxic to human beings.
46 *Ficus glomerata (Cluster fig., Gular)* The bark, leaves and unripe fruits are used during dysentry. Powder of the seed mixed with honey is prescribed for controlling diabetes Bark is used to treat ulcers The root sap is applied to inflammatory glandular enlagements.
47. *Ficus religiosa (Peepal)*: The water after soaking the tender bark for 12-18 hours is used as a diuretic. Dried berries are powdered and consumed to cure spermatorrhoea, nocturnal emission, premature ejaculation and leukorrhea The seeds are laxative and refrigerant. Its leaves and young shoots are used for treating skin diseases. The milky latex is applied to cracked feet The decoction of its bark with five varieties of figs and neem root is used for washing ulcers
48. *Garcinia morella (Indian Comboge tree)*: Seeds contain morellin and guttiferin and are used against Gram positive and negative bacteria
49 *Gmelina arboria (Melina, 'Gambhar')* The leaf decoction is useful for blood purifiction and deworming
50 *Haematoxylon compechianum (Logwood or 'Patang')* The leaf paste is applied to treat bloody piles, gonorrhea and to reduce the burning sensation in the body
51 *Holoptelea integrifolia ('Papri' or 'Kanju')* The tissues of this species have the capacity to increase the rate of fat catabolism.
52. *Lagerstroemia speciosa (Queen crape-myrtle or 'Jarul')*. The leaves have antiglycemic properties
53 *Lawsonia intermis (Henna)* The leaves are used as a prophylactic against skin diseases The paste of leave is used for headache and burning sensation in feet
54 *Madhuca indica (Mahua)* Flower paste with strychos beans is used as an antidote for snake bite The boiled leaves are used to relieve orchitis pains Decoction of the bark is applied to cure itch, bleeding gums and ulcers.
55 *Madhuca latifolia (Madhuka or Mowra)* The leaf juice extracted from boiling water is used as a stimulant The flower decoction is used for treating cough and chronic bronchitis
56 *Mallotus philippensis (Kamela)* The red glandular and hairy substances from the fruits are useful in destroying tapeworms, skin diseases like ring worm and scabies.
57 *Mangifera indica (Mango)* Mango fruit is rich in Vitamin A and C The unripe fruits are eaten for prevention of heatstroke and protection from scorching winds The kernel has medicinal value and is used to treat diarrhoea, excessive bleeding during menstruation and piles The flowers can be used to treat leukorrhea Fruit juice is an astringent tonic for mucus membranes and for treating diphtheria and other throat disorders Leaf decoction with honey is used to treat the loss of voice power Tender

leaves are used to treat diabetes. Leaves and twigs are used as an astringent to treat bronchitis, catarrh, internal haemorrhage and toothache. The bark decoction is used as a mouth wash to cure tooth ache Gum is applied on cracked feet.

58. *Melia azedarach (Persian Lilac or 'Bakan')*: The leaves are used for blood purification, scabies, ring worm, leprosy, leucoderma and to reduce inflammation. The leaf extract is also used to treat cataract.
59. *Michelia champalca (Champac)*: The bark decoction is used to treat mild cases of gastritis and the root is a purgative.

60 *Mimusops elengi (Spanish cherry, 'Maulsari')*: Its fruit and bark are astringent. Seeds are purgative. Fruits and flowers are used to prepare a lotion to cure wounds and ulcers.

61. *Moringa oleifera (Drumstick)*: Its roots contain 'Pterigospermin', which is effective against Gram positive and negative bacteria
62. *Nerium indicum (Oleander, 'Kaner')*: The root and root bark are diuretic and cardiac tonic. The bark and root pastes are used to treat skin disorders. Bark is also used for blood purification.
63. *Nyctanthes abror-tristis ('Parijat' or Tree of sorrow)*: The leaf extract (one tea spoon with honey and salt) is consumed for controlling malaria, instestinal parasites and to control rheumatism. It is recommended to consume 6-7 tender leaves ground with fresh ginger and water, thrice a day for control of recurring fever Fresh leaf juice is mild and safe purgative for infants.
64. *Ocimum sanctum ('Tulsi' or Holy basil)*: The leaves are used for digestion, controlling cold, cough and fever.
65. *Onosma echioides (Ratanjot)*: It is a herb from sub-tropical to temperate region. The leaves of this shrub are diuretic, blood purifier and help to dissolve calculi in the gall bladders and kidney Leaf paste is mixed in oil to treat skin boils.
66. *Pinus roxburghii (Pine)*. Oil of turpentine is obtained from the resin, which is a stimulant and useful to treat chronic bronchitis. Oil is used as a linoment in rheumatic pains.
67. *Populus alba (White poplar) and Populus nigra (Black poplar)*: These species also contain salicin and are used for treating rheumatism or as an analgesic. The bark of *P candidens* and *P trichocerpa* have antifungal properties.

68 *Prosopis juliflora*: The leaf extract is used to treat conjunctivitis. Diluted bark decoction is used to cure sore throat

69. *Pterocarpus indica and P marsupium* Kino juice, obtained by tapping the trunk, is useful to treat diarrhoea. The gum is useful to treat fever and urinary discharges
70. *Punica granatum (Pomegranate)*. Many parts of the tree such as leaf, flower, fruit and root have medicinal properties. The unripe fruit is used in the preparation of digestive powder. The flowers are used as an ingredient to cure miscarriages. Rind acts as an astringent and has a tonic effect on body tissues The root-bark is used to cure intestinal worms. The bark decoction is consumed 3-4 times a day to control blood dysentry and intestinal parasites The flower juice mixed with the juice of Cynodon dactylon is administered to stop bleeding from the nose
71. *Rauvolfia serpentina ('Sarpagandha' or Serpentine root)*. It is a well-known shrub and the dried root with bark is useful for treating insanity, heart ailments and blood pressure. Fresh leaves induce sleep and relieve anxiety.

72 *Ricinus communis (Castor)* The oil is used as a purgative and antidote against poisons

like opium, aconite and snake bites. The dry leaf is smoked to provide relief from hiccups.

73. *Salix alba (Weeping willow)*: The extract contains salicin, which is used as pain reliever.

74 *Salvodera persica ('Chota pilu') and S oleoides ('Pilu')*: The twigs are used as a diuratic and to treat gastritis, hook worm and veneral diseases.

75. *Santalum album (Sandalwood)*: Sandal wood paste is applied externally to treat inflammation Oil is used to treat gonorrhoea, dysuria and cough.

76 *Sapindus emarginatus (Soapnut, 'Reetha')*: Fruit rind is an antidote for snake bite and also useful to treat hemicrania, haemorrhoids and sexual disorders

77 *Saraca indica (Ashoka)*. Bark is a strong astringent and uterine sedative, useful to control excessive menstruation Powdered flower is used to treat haemorrhagic dysentry Seeds are useful for treating urinary discharges.

78. *Simarouba amra* The bark is used as an amoebicide

79. *Spondias pinnata (Hog plum)*: The leaves and bark are astringent and used during dysentry. The leaf juice is applied to treat ear ache The decoction is used to treat gonorrhoea.

80 *Strculia urens (Karaya)*. The gum is used as a mechanical laxative It is also used to cure throat infection

81 *Syzygium cumini (Jambalum, 'Jambhul', Jamun)*: The powdered seed is used for treating diabetes The bark is an astringent and its decoction is used to treat ulcers, dysentry, bleeding gums, sore throat, bronchitis and asthma Bark, fruit and seeds also purify blood

82. *Tabebuia species* The tissues contain 'lapachol', useful for manufacturing chemotherapetic drugs for cancer

83 *Tamarindus indica (Tamarind, Imli)* The fruit is used for treating hyperacidity, nausea and thirst The leaves and seeds are astringent Fruits of 1-2 year old are good for treating atony of liver, stomach and intestines, Flower juice is administered for curing bleeding piles Twigs are used for treating dysentry, evacuant fever, leprosy, opthalmia, oral infections, wounds and respiratory ailments

84 *Tamarix dioica (Farash or Tamarish)* The fruits are used to treat the swelling of spleen and haemorrhoids

85 *Tamarix troupii (Than, Magaphal)* The leaves are used in treating enlarged spleen and fruits are used to stop bleeding

86. *Tecoma species* It contains lapachol, useful for manufacturing drug for cancer Tecoma stans (yellow bells) is a hypoglycemic agent and hence used for treating diabetes

87. *Terminalia arjuna (Arjun)* The bark of the plant is used to treat cough, cold, heart diseases and for healing bone fracture The bark powder acts as an aphrodisiac when taken with milk regularly.

88. *Terminalia bellerica (Belleric myrobalon or Behera)* The fruits are used for stomach disorders, cough and asthma A fine powder of the fruit is used to treat epiphora (watering of eyes) The bark decoction is used for treating skin diseases like leprosy The bark powder is taken daily for curing digestive problems and heart diseases Semi-ripe fruit is a purgative but ripe and dried fruit has the opposite property

89 *Terminalia chebula (Chebulic myrobalan or Harad)* This fruit is part of 'Trifala',

prevents hair from turning gray and also helps in digestion and curing piles, urinary disorders. There are different varieties of 'Harad' found in India and a variety with round shape fruits known as 'Vijay' is most useful for controlling acidity and rheumatism.

90. *Vited negundo (Chinese chase tree or 'Nirgudi')*: The leaves are considered tonic and applied to rheumatic swelling of joints.
91. *Vitex trifoliata ('Pini sanbhalu')*: The leaves are heated and applied to rheumatic pain, swelling and sprains.
92. *Withania somnifera (Winter cherry)*: This is a shrub, known as 'Astghandh'. Its leaves act as a relief for inflammation. The dried root powder acts as an aphrodisiac for treatment of rheumatism lumbago and infertility in women.

ANNEXURE VII *Nutrition garden (promoting nutrients on the common lands and private lands)*

(1) Objectives

The urgent need for replenishment of energy/calories, protein, carbohydrates, fats, vitamins, minerals etc. in proportionate quantities for physical, spiritual and mental development of resource-poor tribal families cannot be ignored. The project aimed at development of nutrition-rich species of fruit bearing trees on village commons. The scheme was launched in 264 villages in Jhabua district.

(2) Resource for malnutrition

Poverty, excessive consumption of liquor, non-availability of high-nutrition food products, misconceptions regarding food production, high birth rate and large family size, migration and illiteracy are the main causes for widely prevalent malnutrition.

(Nutrients in 100 gm of fruit)

Selection of species	*Proteins*	*Fats (gm)*	*Carb (gm)*	*Calories (kcal)*	*Iron*	*Calcium*
Mango	0 6	0 4	16 9	74	1 3	14
Aomla	0 5	0 1	13 7	58	1 2	50
Bair	0 8	0 3	17 0	75	0 5	4
Guava	0 9	0 3	11 2	51	0.27	10
Custard apple	1 6	0 4	23 5	104	4 31	17
Papaya	0 6	0 1	7 2	32	0 5	17
Lemon	1 0	0 9	11 1	57	0 26	70
Moringa	2 5	0 1	3 7	26	0 18	30
Jack Fruit	1 9	0 1	19 8	88	0 56	-

(3) Modalities

(a) The community shall establish nutrition garden on 0 1 ha of common lands or private lands for the above mentioned objectives.

(b) The land selected for the purpose should be fertile and irrigated.

(c) The garden should be socially fenced or should be fenced by protective measures.

(d) The saplings should be sown with 2x2 m spacing in 0.60x0.60x0.60 m size pits.

(e) The species selected should be according to the preferences of the community and the suitability in the existing climatic conditions. There should be intermix of early fruiting trees and late fruiting trees. Similarly, large canopy species should be intermixed with small canopy species

(f) The DRDA suggests the following illustrative mixture of the species on 0.1 ha plot (Mango-18, *Aonla*-27, *Bair*-20, Guava-18, Custard Apple-30, Papaya-36, Lemon-36, *Moringa*-18, Jackfruit-9 = 212). Appropriate modifications may be undertaken by the community.

(h) Certain species like *bair,* custard apple can be taken up on the boundaries of the nutrition garden.

(4) Management

(a) The funding for nutrition garden may be authorised from allocations sanctioned for plantations or horticulture development in the action plan submitted by WDC at the start of watershed project

(b) A "Nutrition Garden Management Committee" should be constituted for those on commons from WDC members. There should not be more than five members. Chairman of WDC should be the chairman of the committee and secretary of the WDC should be the secretary.

(c) The committee shall ensure the security of the garden and its supervision through a roster-wise selection of family (as supervisor) for a day

(d) The committee shall ensure sustainable and equitable management of the nutrition garden

ANNEXURE VIII *Sericulture*

Sericulture requires conditions suitable for mulberry growth. Mulberry being a hardy, perennial plant growing in a wide variety of soil conditions and adaptable to be cultivated as a rainfed crop, it is ideally suitable for India with large amount of wasteland unsuitable for other plants. Farmers are now increasingly prone to take up mulberry cultivation as the returns from it are more than the other crops.

Annual revenue per hectare from different crops:

(Rs/ha/annum)

Crop	*Irrigated conditions*	*Crop*	*Rainfed conditions*
Mulberry	15,000	Mulberry	5,000
Sugarcane	12,700	*Jowar*	550
Paddy	4,500	*Ragi*	750

Firstly, mulberry sprouts throughout the year in tropical India and quality leaves can be harvested by using improved high- yielding varieties and adopting modern practices. Secondly, sericulture is a labour-intensive industry. Sericulture does not require great skill but only delicate handling of the worms and it is ideally suitable for the unskilled family labour , particularly womenfolk, aged, handicapped and children. One hectare of mulberry creates remunerative employment for 12-13 persons throughout the year Thirdly, it is an ideal sideline activity for the rural people engaged in agriculture. During the lean periods of agricultural activity, income is assured by taking up sericulture. Return from sericulture is assured within a month Even people taking up sericulture as a mainline activity are assured regular income at periodical intervals spread throughout the year. Fourthly, it is an ideal cottage industry requiring low initial investment, village-made simple appliances for rearing and reeling, rearing house of simple construction and labourers with little training. Fifthly , all phases of sericulture have a ready market. The markets are supervised by the government in such a way that both the buyer and the seller have benefits. Nothing in sericulture is a waste and the unfed mulberry twigs can be used as fuel, the litter as fertiliser or for biogas production, defective cocoons and reeling wastes for spun silk industry etc

(1) Planning for profitability in sericulture

Farmers taking up this activity should do proper planning in order to get the maximum profit from it. Three things should be considered before taking up sericulture:

(i) availability of suitable land and climatic conditions for the growth of mulberry plant and facilities for carrying out the package of practices for mulberry cultivation,

(ii) suitable climatic conditions and rearing house facilities for healthy and hygienic rearing of silkworms, and

(iii) availability of cheap labour for agricultural and rearing operations.

(2) Choice of rearing times and seasons

The rearing season should coincide with the growth of the mulberry plant In temperate regions (like Jammu & Kashmir), mulberry leaves are available for rearing only during spring and summer These areas are also ideal for rearing bivoltine races. By skillful adjustments of the timing of artificial diapause breaking and incubation, three crops can be harvested In tropical India, mulberry leaves are available throughout the year and silkworms can be reared throughout the year At present, five to six crops are reared per year and rearing is avoided in the rainy season and summer. The number of crops can be increased if *chawki* rearing is done on a cooperative basis, so that farmers rear only late age worms thus reducing labour and time Further, by dividing the mulberry garden into two or three sections and using leaves from one section only for each crop, the quality of mulberry can be maintained throughout the year In both temperate and tropical areas, the season of silkworm rearing should not coincide with the season of other agricultural activities, like harvesting or planting of good crops and cash crops, in order to ensure the availability of labour

(3) Choice of mulberry variety and silkworm races

For maximum yield, the advice of the technical personnel should be sought in the choice of the mulberry variety to be planted The silkworm race to be reared is to be chosen to suit the climatic conditions as well as the mulberry variety available The cuttings and silkworm seed should be purchased only from authorised farms

(4) Choice of the number of larvae to be reared

The number of larvae to be reared per crop depends upon

1. the amount of leaf available,
2. the size of the rearing house,
3. the number of rearing appliances available, and
4. the availability of labour.

The amount of leaf that can be harvested per year from rainfed mulberry is 15,000 kg/ha and from irrigated mulberry is about 30,000-40,000 kg/ha As a minimum of six crops can be reared, the leaf available per crop will be roughly 2500 kg and 5000 kg for rainfed and irrigated mulberry Generally, the mulberry garden is divided into two sections and only one is used per crop For maintaining 100 layings of the improved multivoltine hybrids normally reared, approximately 800 kg leaves will be required Hence, about 300 layings and 600 layings can be reared per hectare of mulberry under rainfed and irrigated conditions respectively. Further, leaf yield is uniform throughout the year in irrigated mulberry but is considerably reduced in summer in rainfed conditions

For rearing about 100 layings, about 150 square feet floor area is required Rearing under crowded conditions will lead to non-uniform growth as well as higher disease incidence For rearing about 100 layings, about four wooden *chawki* rearing trays and 50 circular trays and 40 mountages *chandrika* are required For rearing 100 layings, about eight men are required The peak of the requirement is at instar feeding and spinning stage Per 100 layings, about 40 kg of cocoons can be harvested

(5) Choice of the rearing method

If the facilities are available, it is economic to use cooperative *chawki* rearing centers for rearing early instar larvae This will reduce rearing days, number of missing larvae and labour costs. Choice of rearing method of later instar larvae depends upon availability of space, rearing equipments and method of pruning If space is limited, shelf rearing is to be adopted If space is available, floor rearing reduces expenditure on rearing sheds and equipments as well as time and labour on feeding and bed-cleaning If whole shoot harvest or branch cutting is done, floor rearing is advisable

ANNEXURE IX *Biogas plant*

The gas which is produced by the anaerobic digestion of the organic wasted material is known as biogas This gas is highly inflammable Biogas is mainly a mixture of methane and carbon dioxide. In addition, a small amount of hydrogen and trace amount of hydrogen sulphide and ammonia may also exist. The composition of the gas is given below :

Composition of gas	*% precent*
Methane	55-65
Carbon dioxide	35-45
Hydrogen	trace
Hydrogen sulphide	trace
Ammonia	trace

The digestion of the organic waste matter occurs in the absence of air (the anaerobic condition). This leads to biogas production And the slurry can be used as a good manure.

(1) Favourable factors influencing the biogas production

Nutrients	C N = 30:1 (may vary from 20 1 to 40 1)
Solid concentration	12% (8% volatile matter)
Temperature	35^0C (less than 15^0 is not favourable for gas generation)
Retention period	30-55 days (it varies from place to place)
pH	6 6-8 0 (7.2 pH is the optimum for gas generation)
Toxic substance	Fungicides, insecticides, pesticides, heavy metals, detergents, phenyl, dettol etc, are harmful for gas generation
Mixing	It is required to prevent the digester from scum formation

(2) Feed material

One of the feed materials for biogas generation is the cowdung/cattle dung which is available in large quantities. Other animal wastes like poultry litters, pig droppings and other animal wastes can also be used for gas generation. The amount of raw materials that are available from different animals:

Name of the animals	*kg/day*
Buffalo	15
Horse	10
Cow	10
Calf	5
Sheep/goat	2
Pig	2
Human	0 4
Poultry bird	0 18

The amount of gas produced from different animal wastes is as follows

Source	*m^3/kg (wet basis)*
Cattle	0 04
Poultry bird	0 06
Pig	0 08
Buffalo	0 04
Sheep/goat	0 05
Elephant	0 02
Night soil	0 10

(3) Installation guidelines for family size biogas plants

(a) Prerequisites

Basic inputs for family size biogas plants are animal dung and water It should, therefore, be ascertained as to whether there is an adequate supply of these inputs. Also, there should be sufficient free space available to build the gas plant and manure pits for storing outlet slurry.

(b) Technical feasibility

Family size biogas plant is intended to meet the domestic fuel needs mainly for cooking and also for lighting. It has to be ascertained that animal dung in sufficient quantity to produce enough gas to meet the fuel need is available The case where the availability of dung matches the requirement of gas or exceeds it may be considered as technically feasible To decide about the feasibility of a proposal, it is necessary to have a broad (i) requirement of biogas for various uses, and (ii) quantity of biogas that could be obtained from various animal wastes

(c) Requirement of biogas

The requirement of biogas for various needs could be summarised as follows
Cooking 8 to 10 cft (0 23 M^3 to 0 29 M^3)/person/day
Lighting 4 5 to 5 cft (0 13 M^3 to 0.14 M^3) /hr for single mantle lamp of 100 cp
Motivepower . 15 cft (0 45 M^3)/hr/HP

(d) Quantity of biogas that could be obtained from various animal wastes

In case of family size biogas plants, first of all a verification is to be made about the availability of the number of cattle, pigs, poultry birds, etc In respect of cattle, it is to be ascertained whether they are stable bound or grazing type It is preferable to actually measure or weigh the quantity of dung available in 24 hours and then to calculate the possible capacity for gas generation unit Alternatively, calculations could be made on the basis of the particulars given above Thus, the availability of raw material and requirement of gas in a given place is known It is easy to decide the capacity (size) of the biogas plant required in the given place

(e) Deciding the capacity (size) of a family size biogas plant

It is better to illustrate this with an example instead of a long description. We may consider the following case for deciding the size:

Number of cattle available	
Buffalo	3 medium size, stable bound
Bullocks	4 taken out for agriculture operations during the day
Goat	2 stable bound
Calf	1 stable bound
Requirement of gas	
Cooking	8 family members (adults)
Lighting	2 lamp of 100 candle power for 4 hours daily

(f) Calculation of dung availability

Buffaloes are of medium size and stable bound. Hence, dung production would be:

3 x 15 kg = 45 kg/day (A)

Bullocks are away for work during the day. Hence collection of dung during the night only should be taken into account, which would be fixed at 60% of the daily production If we put the dung production at 10 kg/bullock/day, then the daily production of dung would be 6 kg/day/bullock.

Therefore,

Dung production from bullocks,

5 x 6 kg = 24 kg/day (B)

Dung production from 1 goat,

1 x 4 kg = 4 kg/day (C)

Dung production from 1 calf,

1 x 5 kg = 5 kg/day (D)

Total availability of dung = A+B+C+D

i e , 45 + 24 + 4 + 5 = 78 kg/day

Gas generation,

78 kg x 0.04 M^3 = 3 12 M^3 /day (X)

(g) Requirement of gas

Cooking for 8 persons daily,

8 x 0.28 M^3 = 2 24 M^3/day

Lighting one lamp single mantle for 4 hours daily,

4 hrs x 0.14 M^3 = 0 56 M^3/day

= 2.80 M^3/day (Y)

Since, X > Y

Therefore, the proposal is sound.

Since the requirement of gas is 2 80 M^3/day , the capacity of the plant which is very near to this requirement 3 M^3/day, hence, a biogas plant of 3 M^3/day is recommended.

(4) Selection of site

The site for biogas plant should be.

(a) as nearer as possible to the source of animal waste (say cattle shed) Minimum labour would therefore be required for daily feeding;

(b) as nearer as possible to the points of utilisation (say kitchen). This would help in minimising cost on pipe line for delivery of gas, since a pipe of smaller diameter could be used without much pressure drop, over a short distance,

(c) a place with enough open space to build the biogas plant and also for manure pits by its side, to store the digested slurry (effluent),

(d) a place fully exposed to sunlight,

(e) away from a drinking water well or a similar source of water; safe distance is 15 m,

(f) there should not be big trees near the site selected, since they may prevent the sun's rays falling on the biogas plant and the roots may cause damage to the digester,

(g) the site should be slightly at a higher elevation than the surroundings, and

(h) the edge of the biogas plant should be about 2 m away from the foundation of the house or any other building.

ANNEXURE X *Various formats used in pra surveys/techniques (illustrative)*

(A) Format for terrain feature data

Date of survey Block Sheet No
Phaliya (hamlet) Village GP

Survey no with sub-division, if any						
Type of possession						
Type of landform						
Surface material						
Soil texture						
Soil drainage						
Soil colour						
Soil depth						
Degree of erosion						
Type of erosion						
Soil quality						
Soil conservation measures, if any						
Land classification in local terminology						
Describe type of land problem, if any, in users' perception						

N B The columns have to be filled up based on friendly dialogue and careful observation

Itemwise key to each column is given below Choose the letter corresponding to the appropriate answer, wherever given

1. The survey no and sub-division no of the plot as given in the map
2 A Private B Government C. Vested
3. A Valley floor B. Graded valley slope C Terraced valley slope D Lower plain
E Upper plain F Gentle hill slope G Moderate hill slope H. Steep hill slope
I. Flat hill top J Flat ridge top K Hill crest L Ridge crest
4 A.Alluvium B Colluvium C Laterite D Residuum/weathered material
E Rocky stretch with incipient soil
5 A Sand B Loam C Clay D Sandy clay
6 A Well drained B Moderately drained C Poorly drained
7 A Dark B Black C Yellow D Red
E White
8 A Very shallow (0-25cm) B Shallow (25-50cm) C Medium (50-100cm) D Deep (1m)
9 A Severe B Moderate C Light
10 A Rill B Gully C Sheet D Slope failure
11 A Alkaline B Acidic C Saline D Neutral
E Unknow
12 A Naturally conserved B Vegetative bunding C Soil/Rock bunding D Cemented bunding
13 A User B Infertile C Water logged D Fertile
E Productive
14 A Soil erosion B Waterlogging C Drought condition D Cracks
E Salinity/alkalinity F Sedimentation

(B) Format for land use status data

Date of survey Block Sheet No
Phaliya (hamlet) Village GP

Survey no with sub-division, if any						
Land use pattern						
Crops grown						
Inter-crops, if any and name						
Crop rotation, if any and sequence						
Productivity trend						
Irrigation status						
Land utilisation level						
Reason for low utilisation of land						
Type of fertiliser used						
Use of chemical pesticides						
Users' perception on whether land is properly used or not and the desirable landuse						

N B The columns have to be filled up based on friendly dialogue and careful observation

Itemwise key to each column is given below. Choose the letter corresponding to the appropriate answer, wherever given.

1 The survey no and sub-division no of the plot as given in the map
2 A Seasonal crops B Annual crops C Plantations D Tree crops
E Forest F Built up area G Fallow
3 Name of trees or crops grown
4 Name of inter-crops, if any

5 If crop rotation is practised, then write the sequence of crop (e g , If paddy, vegetable and pulses are the first, second and third crop respectively, then write Pl-V-Pu)

6 A Increasing B Steady C Decreasing

7 A Irrigated from canal water B Irrigated from pond/tank/ dugwell C Irrigated from bore/ tubewell D Not irrigated

8 No of crops taken from the plot per year

9 A Partial degradation B Lack of irrigation C Shortage of fund D Lack of labour E Lack of market F Low/ no profit

10 A Chemical B Cowdung and ash C Green manure D Others

11 A Yes B No

12 Write the extracted opinion of the land user on his/her perception on the present land use and, desirable land use

(C) Format for water utilisation status data

Date of survey Block Sheet No

Phaliya (hamlet) Village GP

Survey no with sub-division, if any						
Water extraction structure no						
Ownership (type)						
Construction year						
Perenniality						
Dimension(m x m)						
DTWT bgl(m)						
DTWB bgl(m)						
Type of water bearing formation						
Portion of well lined						
Length of lining(m)						
Yearly water table fluctuation(m)						
Water quality						
Use						
No of people using the source						
Mode of drawal						
Pumping duration(mnt)						
Drawdown on pumping (m)						
Recuperation time (mnt)						
Pumping frequency						
Mode of distribution						
Area irrigated (acres)						
Distance to source of pollution(m)						
Effect of pumping on nearest source						
Maintenance status						
Level of exploitation						
Remarks including measures to be taken for better upkeep of the water source						

N B To be filled up based on field measurements/inferences from local people

Itemwise key to answers or details required in each column are given below. Choose the letter corresponding to the appropriate answer, wherever given.

1 The survey no and the sub-division no. of the plot as given in the map

2 The serial number given to each water extraction structure in a plot as noted in the map (e g , for, dugwells- W1, W2, W3, etc., for ponds- P1, P2, P3, etc , for tubewells- T1, T2, T3, etc)

3 A Private B Government C Community D Temple, mosque etc

4 If the year of construction is not exactly known, write X for well less than five years and Y, for wells greater than five years

5 P- for perennial (if water is available throughout the year)
S- for seasonal (if water is not available throughout the year)
I- for induced (if water availability is due to seepage from nearby canal)

6 Write length and breadth for square well/pond or diameter for round well/pond and width, for stream/canal

7 Depth to the bottom of the well from the ground level

8 Depth to the bottom of the well from the ground level
N B For tubewells, collect data from local enquiries or secondary data

9 A Sand B Clay C Laterite D Weathered rock
E Fractured rock F Massive rock

10 A Top B. Middle C Bottom D Complete

11 Measure the extent of the lining(protected sidewall of well) in metres

12 Infer the highest water level attained during monsoon and lowest water level during summer and calculate the difference

13 A Good B Unusable C Hard D Saline
E Turbid

14 A Drinking B Bathing C Irrigation D Industrial
E Unused
(If used for more than one purpose, write all relevant letters)

15 Write the total number of people using the source

16 A Bucket and rope B Bullock C Electric pump D Diesel pump
E Wind pump F Solar pump G Others

17 Write the total duration of pumping in minutes per day

18 Write the difference between the water level before and after pumping

19 Infer the time taken for the water level after pumping to attain the original water level, before pumping

20 Infer the number of pumping operation carried out per day

21 A Pipeline B Cemented canal C Earthen canal D Flooding

22 Infer the total area irrigated using the single source

23 Distance of source(well/pond/stream etc) from the latrine, garbage dump, waste water, drainage, biogas installation, etc

24 A No effect B Decreasing water level C Increasing water level

25 A Silted B Caved C None D Well-maintained

26 A Overexploited (continuous water tabel lowering over the years due to pumping)
B Optimally exploited (no noticeable change in water table over the years even on pumping)
C Underexploited (no considerable lowering of water table after pumping even during summer)

(D) Format for drinking water and sanitation status survey

Phaliya (hamlet) Revenue village
Gram Panchayat Block
Date of survey Plot No

1 Name of the family head

2 Respondent ☐ A Family head B Housewife C Other family members D Others

3 No of persons in the family Male Female

Children below 5 yrs Total

4 Source of water ☐ Drinking ☐ Bathing ☐ Irrigation

Own	A Dugwell	B Handpump	C Pond/tank	D Tap
Public	E Dugwell	F Handpump	G Pond/tank	H Tap
Neighbour's	I Dugwell	J Handpump	K Pond/tank	L Others

5 Distance ot drinking water source(in kilometre)

6 Months of water shortage

7 Distance to source during scarcity period

8 Whether the source is satisfactory ☐
A Yes
B No

9 If no, specify reasons ☐
A Poor quality
B Insufficient quantity
C Distant source
D Others

10 Type of sanitation facility ☐
A Own latrine
B Own compound
C Community latrine
D Open ground/canal/river/road

11 Type of latrine ☐
A Twin leach pit
B Septic tank
C ESP
D Others

12 Disposal of waste ☐
A Drainage system
B Open canal/stream
C House premises
D Waste material pit
E Others

(E) Format for socio-economic and health status survey

Date of survey Block GP

Village *Phaliya* (hamlet) Plot No

1 Name of the head of family

2 No of residents in the house Male Female

Children below 5 yrs Total

3 No of illiterates (5-40 age group) Male Female Total

4 Type of house

(a) Roof	☐	A Straw/leaf	B Sheet	C Tiles
		D Concrete	E Others	
(b) Walls	☐	A Straw/leaf	B Sheet	C Wood panel
		D Mud	E Brick/stone	
(c) Floor	☐	A Mud/sand	B Cowdung	C Wood panel
		D Cement	E Mosaic	F Tiles

(d) Kitchen ☐ A Indoor B Outdoor C.With chimney
D No chimney

(e) Latrine ☐ A Indoor B Outdoor C.Community
D No facility

(f) No of rooms .. . (exclude kitchen, bathroom and toilet)

(g) Electrification ☐ A Yes B No

(h) Ownership ☐ A Self-owned B Rented C Undivided family prperty

5. Fuel used (a) Lighting ☐ A Kerosene B Firewood C Candle
D Electricity

(b) Cooking ☐ A Firewood B Biowaste C Biogas
D Petroleum gas E Kerosene F Electricity

6. Type of stove ☐ A Open hearth B Closed hearth C Kero stove
D Efficient choola E Electric stove F Gas stove

7 Inventory on family members

Name	Age	Sex	Marital status	Education	Employment status	Place of employment	Place of residence	No of Days residing in GP/year
1	2	3	4	5	6	7	8	9

iv M. Married U Unmarried
v A Illiterate B Literate without school going C Class 1-4 D Class 5-7
E Class 8-10 F Class 10+2 G ITI H Diploma
I Degree in Arts J Degree in Science K Computer L. Degree in Commerce
M Masters Degree N Ph D O Degree in Engineering
P Degree in Medicine Q Others
vi A Employed B Self-employed C Unemployed D Registered unemployed
vii Within the A GP B Block C District D Others
viii Within the A GP B Block C District D Others

8 Assets of the family

Area of landholding (acres)		Area cultivated (acres)		Building on rent	Vehicles and type	Other assets
Inside GP	Outside GP	Inside GP	Outside GP	Total No	Total No	Total No

9 Details on animal husbandry (number and income)

Cows	Bufflaoes	Bullocks	Goats	Pigs	Chicken	Duck	Others	Annual income

10 Employment and income of family members

Name of the employed family members	Primary employment/secondary employment						Income from other assets (Rs)	Total income (Rs)
	Employment code	No of days employed	Income (Rs)	Employment code	No of days employed	Income (Rs)		
i	ii	iii	iv	v	vi	vii	viii	ix

Employment codes

A Farmer

B Farmer and agri labour

C Agri labour

D Skilled labour

E Unskilled labour

F Factory owner

G Fact employee

H Govt servant

I Trader

J Student

K Others

11 For children below five years

Name	Age	Sex	BCG 0/1	Polio 0-5	Measles 0-5	DPT 0-5	Diarrhoea Y/N	Worms Y/N

If no vaccine is given, write 0, 1, 2 or 3 to indicate number of times the vaccine is given

12 Any child born in last one year Yes/No Number

13 Any death in last two years Yes/No Number

Male Age yrs months

Female Age yrs months

14 Cause of death A Pregnancy associated

B Others(specify name)

15 Does anybody in the family suffer or suffered from the following illness in the last two years

Name	Illness

A Prolonged fever (over two weeks)

B Goitre

C Diarrhoea

D TB

E Jaundice

F Typhoid

G Encephalitis

H Fluorosis

I Malaria

J Others

16 No of handicapped persons, if any, in the family

(F) Tables for consolidation of data from maps and data formats

(I) Distribution of land in different forms (area in acres)

Name of revenue villages	I	II	III	IV	Total	%
Landform						
Valley-floor						
Valley-graded/terraced slope						
Lower plain						
Upper plain						
Gentle slope						
Moderate slope						
Steep slope						
Flat topped hill or ridge						
Hill/ridge crest						
Total						

(II) General land use classification (area in acres)

Name of revenue villages	I	II	III	IV	Total	%
Land use						
Agricultural land						
(i) Seasonal						
(ii) Annual						
(iii) Plantation						
(iv) Tree crops						
Inter-cropping						
Crop rotation						
Natural forest						
Social forest						
Degraded forest						
Scrub land						
Grass land						
Unused land						
(i) Usable						
(ii) Stony						
(iii) Degraded						
Builtup area						
Wet land						
(i) Saline water						
(ii) Fresh water						
(iii) Induced						

Mines (in use)						
Mines (abandoned)						

(III) Distribution of surface material (area in acres)

Name of revenue villages	I	II	III	IV	Total	%
Surface material						
Alluvium						
Colluvium						
Laterite						
Residuum						
Rocky with incipient soil						
Total						

(IV) Crop distribution (area in acres)

Name of Revenue Villages	I	II	III	IV	Total	%
Crop types						
Paddy-kharif-P1						
Paddy-winter- P2						
Paddy- rabi- P3						
P1+P2+P3						
P1+P2						
Wheat						
Vegetable						
Pulses						
Oilseeds						
Cereals						
Sugarcane						
Fodder						
Banana						
Mixed crops						
Coconut						
Arecanut						
Cashew						
Mango						
Guava						
Rubber						
Fuelwood						

(V) Type of evironmental poblems and the pot numbers

Name of revenue villages	I	II	III	IV	Total	%
Environ problems						

Drainage related						
Erosion						
Pollution						
Salinity						
Seasonal flooding						
Agricultural						

(VI) Irrigation, land utilisation and productivity (area in acres)

Name of revenue villages	I	II	III	IV	Total	%
Details						
Irrigated land						
Land utilisation level						
(i) Low						
(ii) Moderate						
(iii) High						
Productivity						
(i) Increasing						
(ii) Steady						
(iii) Decreasing						

(VII) Water-related details

Name of revenue villages	I	II	III	IV	Total	%
Details						
No of wells						
Dugwells-seasonal						
Dugwells-perennial						
Dugwells-pumping						
Tubewells-seasonal						
Tubewells-perennial						
Tubewells-pumping						
Dug-cum-bore-seasonal						
Dug-cum-bore-perennial						
Stepwell-seasonal						
Stepwell-perennial						
Stepwell-pumping						
Ponds-seasonal						
Ponds-perennial						
Ponds-pumping						
Reservoir-seasonal						
Reservoir-perennial						
Length of perennial stream						

Length of seasonal stream						
Length of irrigation canal						
Dugwell requiring maintenance						
Tubewell requiring maintenance						
Stepwell requiring maintenance						
Ponds requiring maintenance						
Reservoir requiring maintenance						
Length of stream for maintenance						
Length of canal for maintenance						
No of overexploited wells/ponds						
Optimally exploited wells/ponds						
Underexploited wells/ponds						

(VIII) Details on community facilities

Name of revenue villages	I	II	III	IV	Total	%
Details						
Length of surfaced roads (km)						
Length of unsurfaced roads (km)						
Length of lane (km)						
Length of foot path (km)						
No of foot bridge						
No of ferry service						
Pump house- drinking water						
Length of water supply pipelines (km)						
No of standposts						
No of post offices						
Health centres						
Pre-primary schools and students						
Primary schools and students						
Upper primary schools and students						
High schools and students						
Colleges and students						
Other institutions and students						
No of reading rooms/library						
No of community halls						
No of markets						
No of cooperative societies						
No of public distribution shops						
No of banks						
Length of electirc transmit line (km)						

No of transformers						
No of cottage industries						
No. of small industries						
No of major industries						

(IX) Distribution of population

Name of revenue villages	I	II	III	IV	Total	%
Population						
Male						
Female						
Children below 5 years						
No of illiterates						
(5-40 age)						

(X) Drinking water (enter number of househods)

Name of revenue villages	I	II	III	IV	Total	%
Source of water						
Own well/ tubewell						
Own pond						
Public well/ bore						
Public pond						
Neighbours' well						
Neighbours' pond						
Other source						

(XI) Bathing water (enter number of households)

Name of revenue villages	I	II	III	IV	Total	%
Source of water						
Own well/ tubewell						
Own pond						
Public well/ bore						
Public pond						
Neighbours' well						
Neighbours' pond						
Other source						

(XII) Irrigation water (enter number of households)

Name of revenue villages	I	II	III	IV	Total	%
Source of water						
Own well/ tubewell						
Own pond						

Public well/ bore						
Public pond						
Neighbours' well						
Neighbours' pond						
Other sources						

(XIII) Sanitation facility (enter number of households)

Name of revenue villages	I	II	III	IV	Total	%
Type						
Own latrine						
Own compound						
Community latrine						
Open ground/canal/river/road side						

(XIV) Drainage facility (enter number of households)

Name of revenue villages	I	II	III	IV	Total	%
Type						
Drainage system						
Open canal/ stream						
House premises						
Waste material pit						
Others						

(XV) Details on housing (enter number of households)

Name of revenue villages	I	II	III	IV	Total	%
Details						
Roof- straw/leaf						
Walls- straw/ leaf						
Floor- mud/ sand/ cowdung						
Kitchen- without chimney						
Kitchen- open air						
House- without latrine						
House- electrified						
House- without electrification						
House- rented						
House- undivided family						

(XVI) Fuel for lighting (enter number of households)

Name of revenue villages	I	II	III	IV	Total	%
Fuel						
Kerosene						
Firewood						
Electricity						

Candle						
Others						

(XVII) Fuel for cooking (enter number of households)

Name of revenue villages	I	II	III	IV	Total	%
Fuel						
Firewood						
Biowaste						
Biogas						
Petroleum gas						
Kerosene						
Electricity						
Others						

(XVIII) Animal husbandry

Name of revenue villages	I	II	III	IV	Total	%
Animal/ birds						
Cows						
Buffaloes						
Bullocks						
Goats						
Pigs						
Chicken						
Duck						
Others						
Annual income (total)						

(XIX) Family assets

Name of revenue villages	I	II	III	IV	Total	%
Details						
No of families						
Area of land owned-inside GP						
Area of land owned-outside GP						
Area cultivated-inside GP						
Area cultivated-outside GP						
Buildings on rent						
Vehicles						
Others						

(XX) Population Agewise distribution (male)

Name of revenue villages	I	II	III	IV	Total	%
Age group						
0-5						

6-15						
16-35						
36-60						
Over 61						

(XXI) Population Agewise distribution (female)

Name of revenue villages	I	II	III	IV	Total	%
Age group						
0-5						
6-15						
16-35						
36-60						
Over 61						

(XXII) Residential status (enter number of people)

Name of revenue villages	I	II	III	IV	Total	%
Place						
Within GP						
Within block						
Within district						
Within country						

(XXIII) Educational level (enter number of people)

Name of revenue villages	I	II	III	IV	Total	%
Education						
Illiterates*						
Literates without school going						
Class 1-4						
Class 5-7						
Class 8-10						
Class 10+2						
Degree						
Masters Degree						
Professional						
ITI						
Diploma						
Others						

* Children below five years are excluded

(XXIV) Employment status (enter number of people)

Name of revenue villages	I	II	III	IV	Total	%
Employment status						

Unemployed						
Registered unemployed						
Self-employed						
Employed						

(XXV) Place of employment (enter number of people)

Name of revenue villages	I	II	III	IV	Total	%
Place						
Within GP						
Within block						
Within district						
Within country						

.(XXVI) Distribution of population as per primary employment

Name of revenue villages	I	II	III	IV	Total	%
Employment						
Farmer						
Farmer and agricultural labour						
Agricultural labour						
Skilled labour						
Unskilled labour						
Self-employment						
Government servant						
Factory employee						
Factory owner						
Business						
Animal husbandry						
Others						

(XXVII) Distribution of population as per secondary employment

Name of revenue villages	I	II	III	IV	Total	%
Employment						
Farmer						
Farmer and agricultural labour						
Agricultural labour						
Skilled labour						
Unskilled labour						
Self employment						
Government servant						
Factory employee						
Factory owner						

Business						
Animal husbandry						
Others						

(XXVIII) Sectorwise income (in Rs)

Name of revenue villages	I	II	III	IV	Total	%
Sectors						
Primary employment						
Secondary employment						
Other assests						
Total						

(XXIX) Vaccination status (enter number of people)

Name of revenue villages	I	II	III	IV	Total	%
Vaccine						
BCG						
Polio						
Measles						
DPT						
Diarrhoea						
Worms						

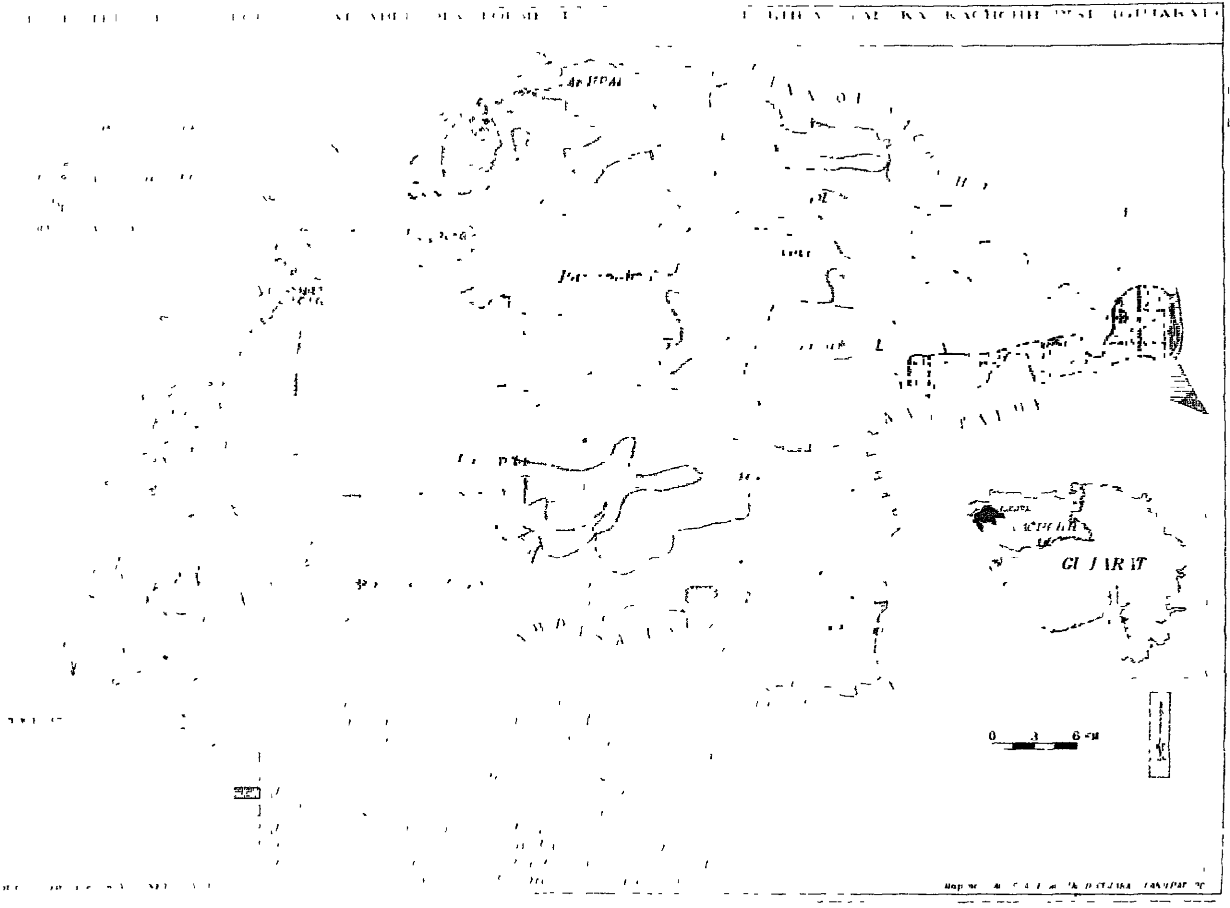
(XXX) Birth and death (enter number of people)

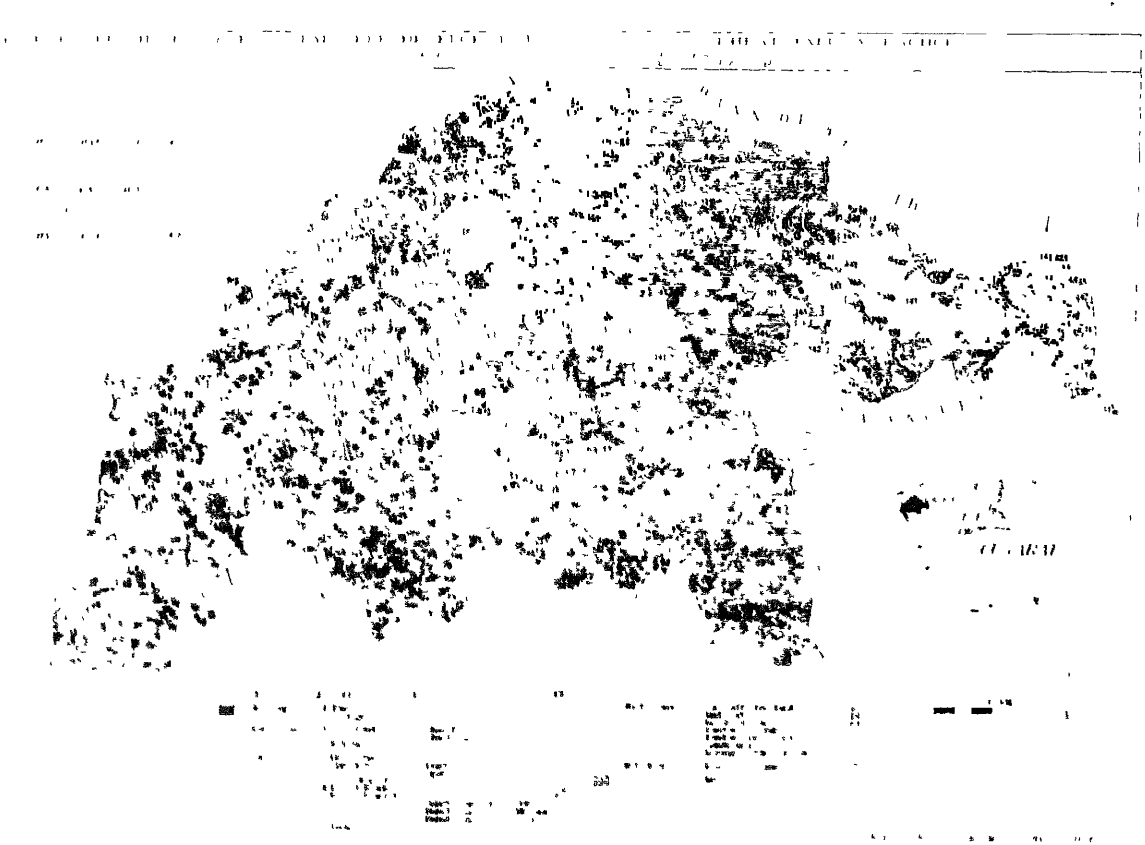
Name of revenue villages	I	II	III	IV	Total	%
Details						
Birth in last 1 yr						
Birth in last 2 yr						
Pregnancy associated death						

(XXXI) Illness (enter number of people)

Name of revenue villages	I	II	III	IV	Total	%
Illness						
Prolonged fever						
Goitre						
Diarrhoea						
TB						
Jaundice						
Typhoid						
Encephalitis						
Fluorosis						
Malaria						
Others						

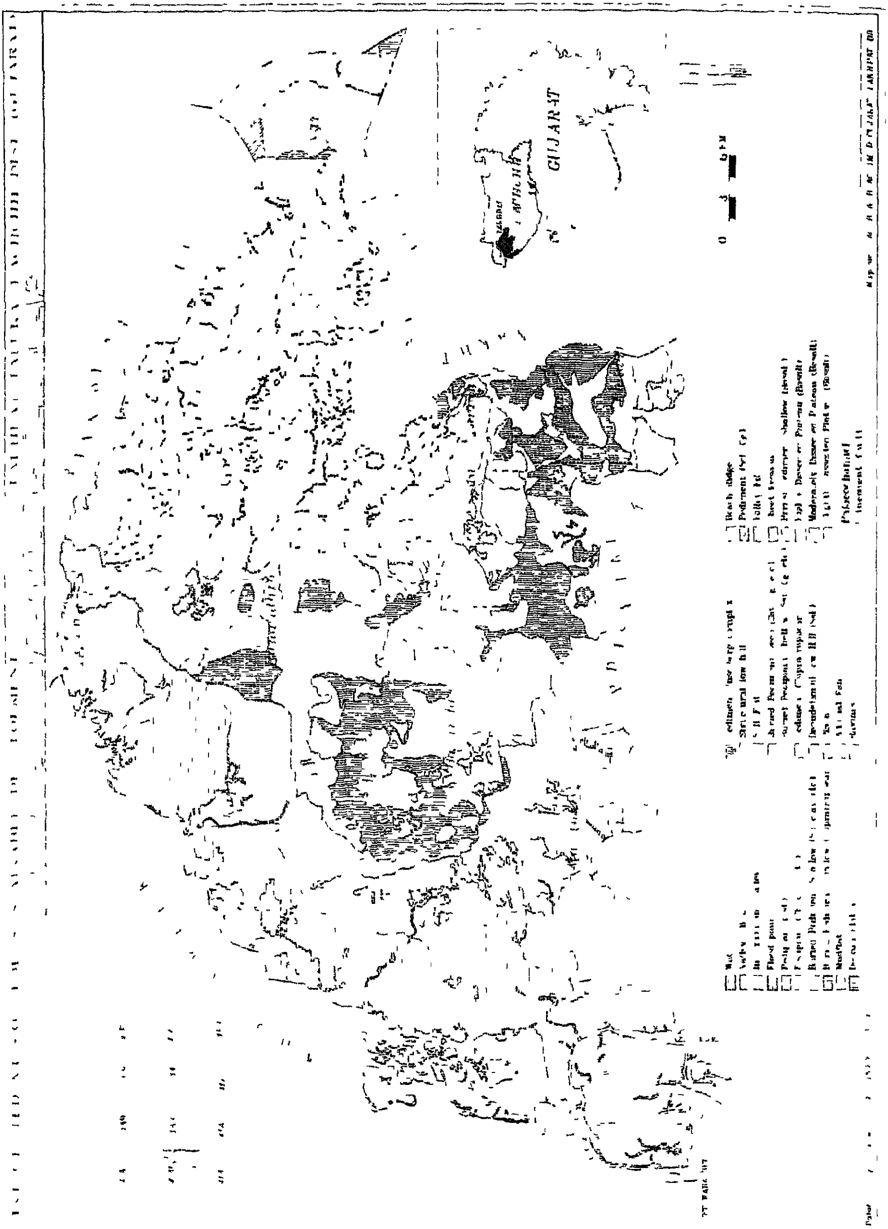
Appendix 1 *Thematic soil map*





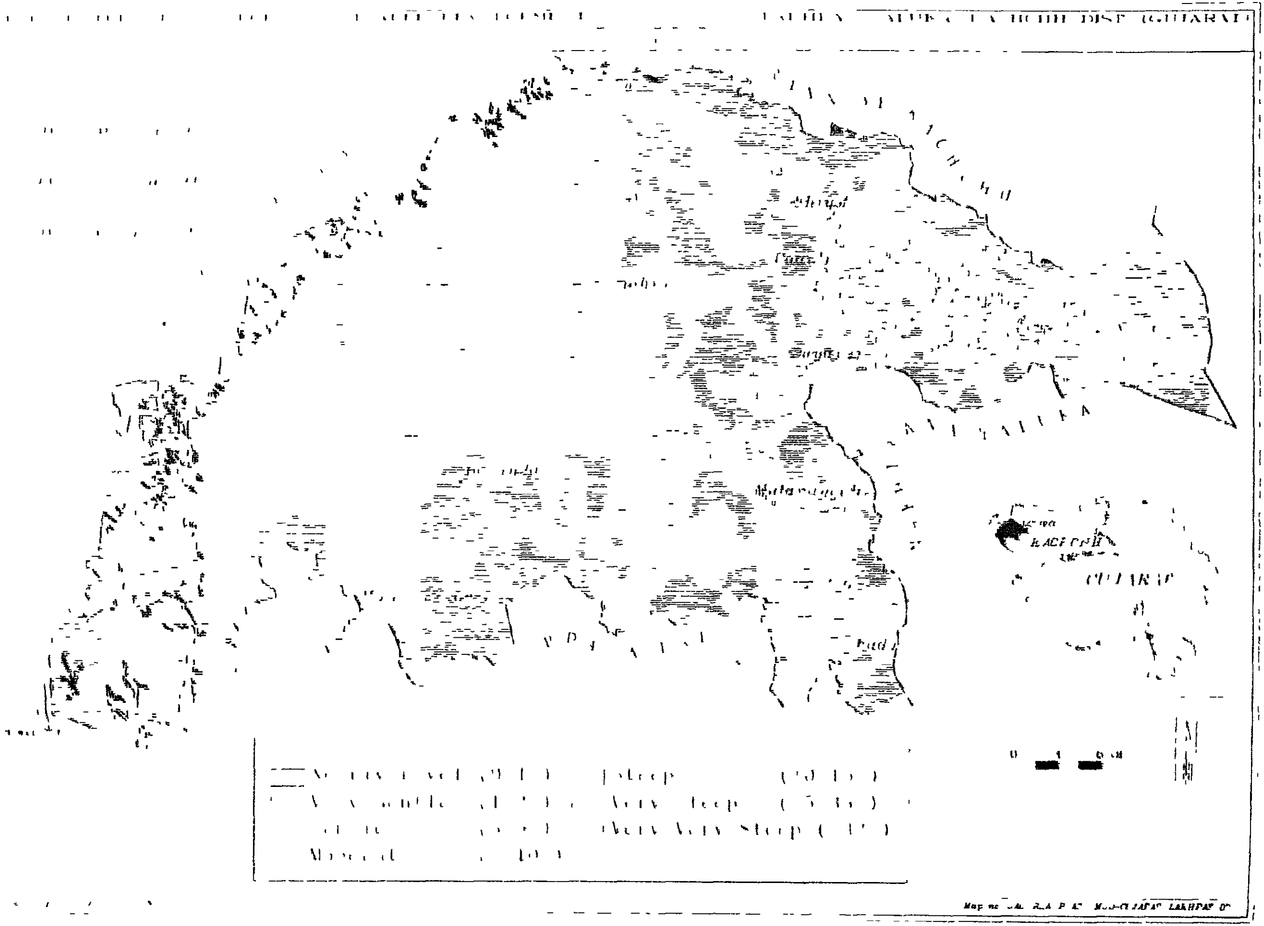
Appendix 2 *Thematic land use/land cover map*

Appendix 3 *Thematic hydro-geomorphological map*

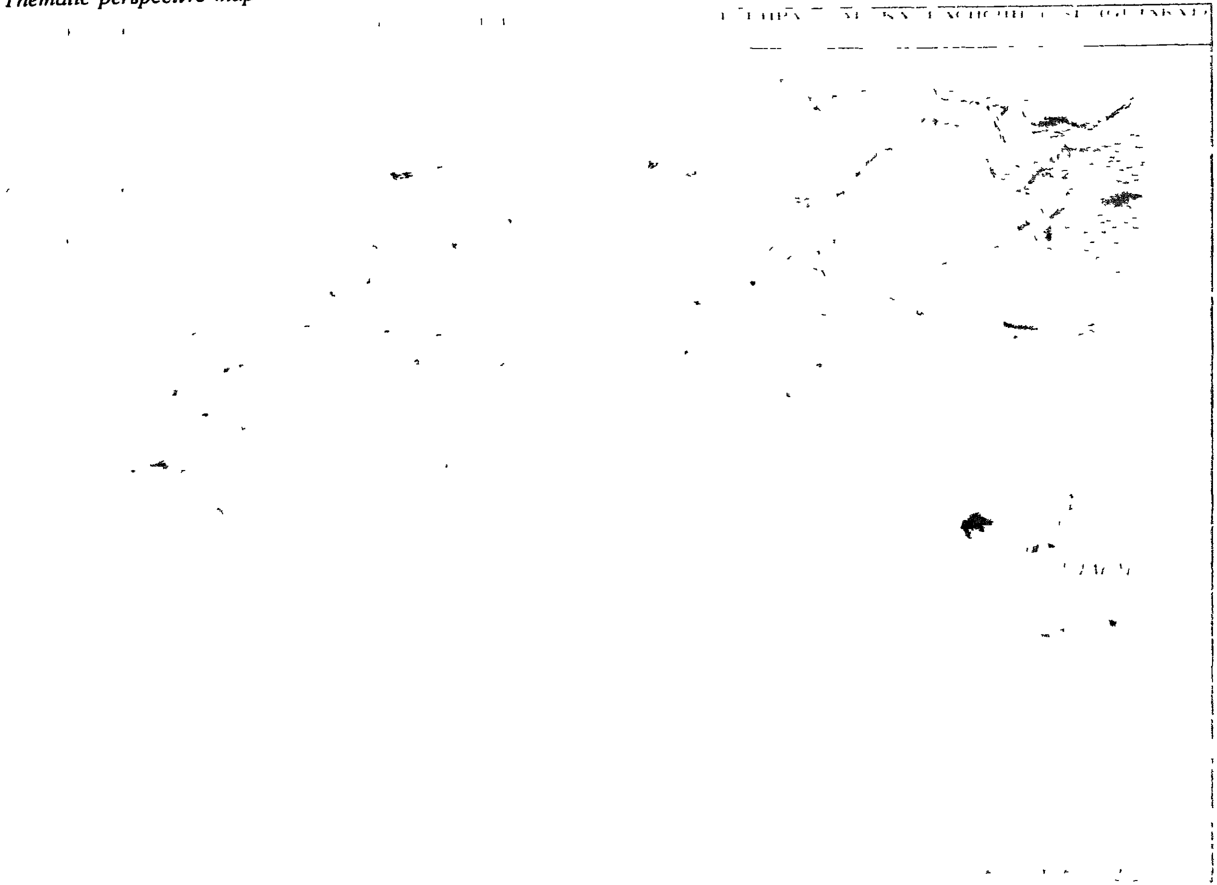


Appendix 4 *Thematic groundwater prospect map*

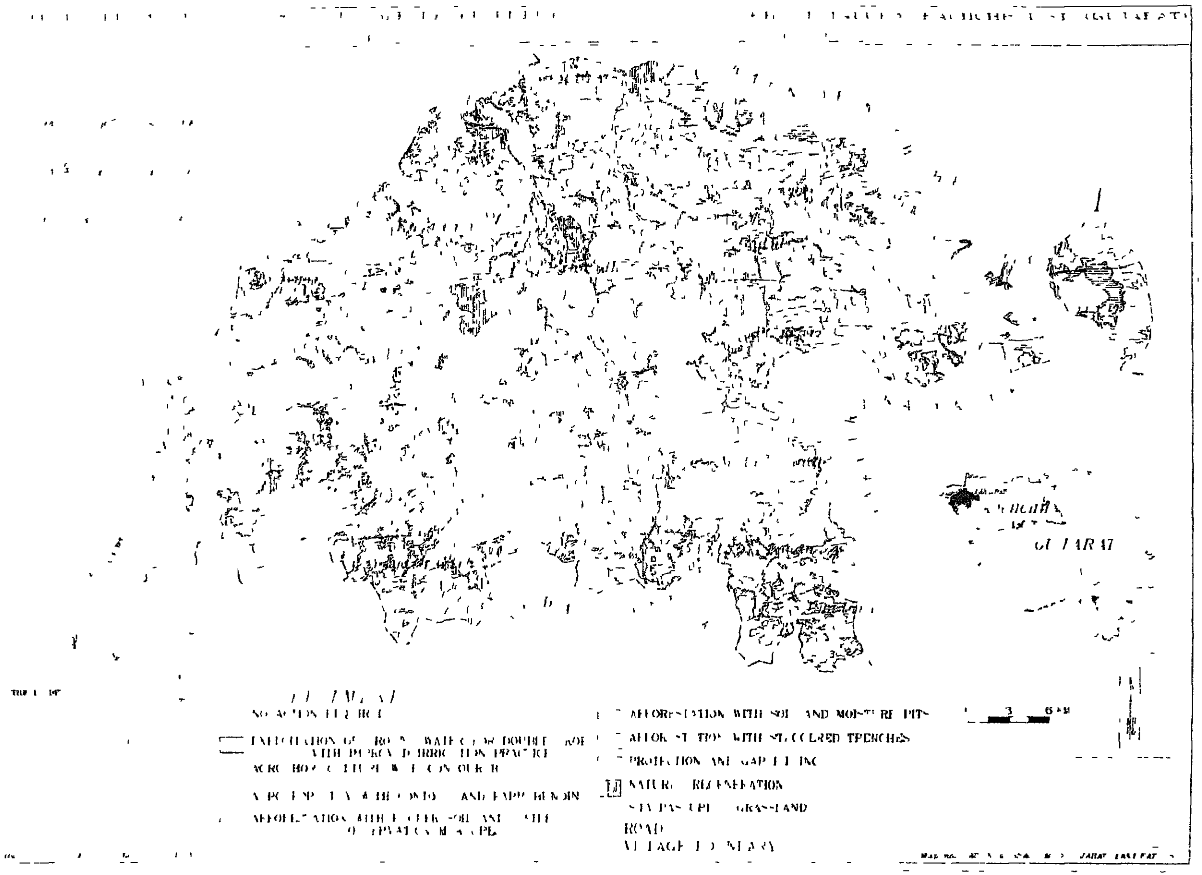
Appendix 5 *Thematic slop map*

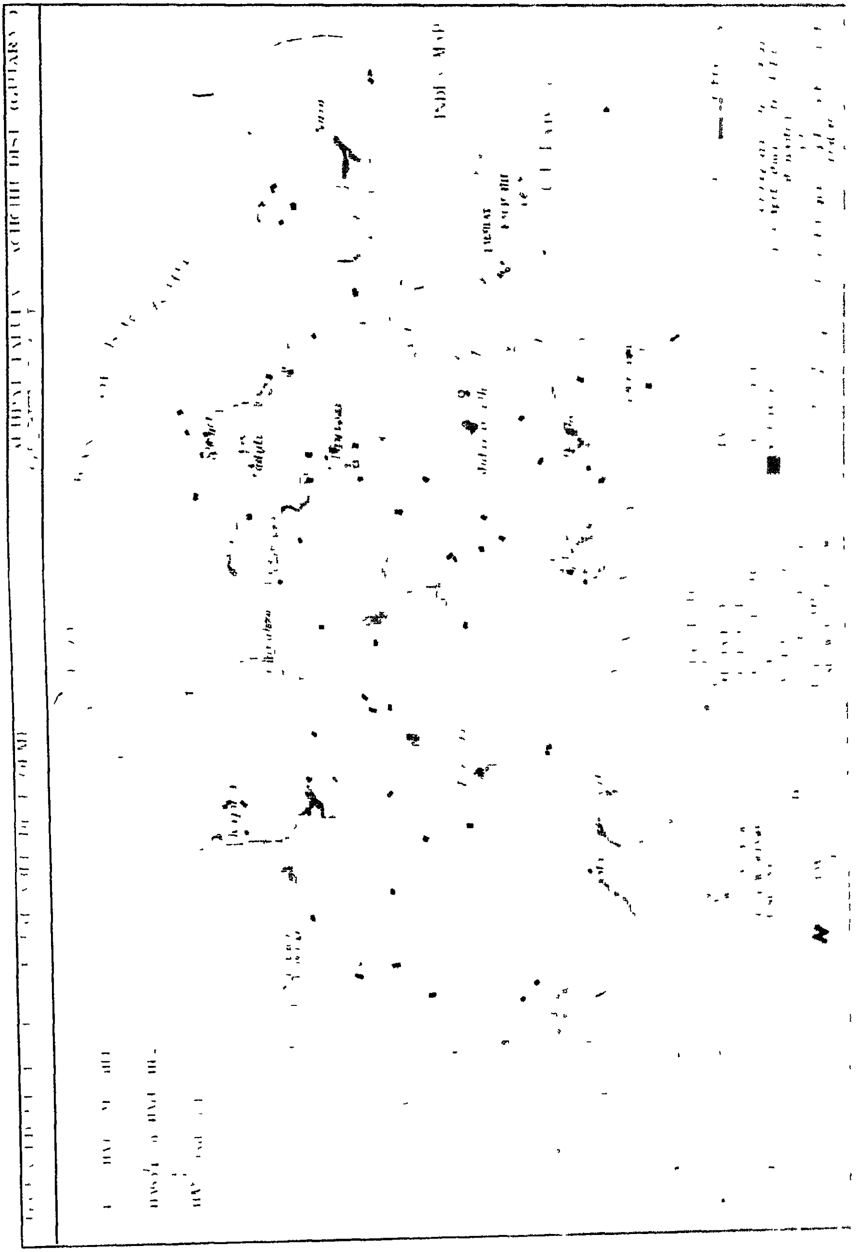


Appendix 6 *Thematic perspective map*



Appendix 7 *Thematic land resources development plan map*


GUJARAT
3
6 KM
NO ACTION REQUIRED
AFFORESTATION WITH SOIL AND MOISTURE PITS
AFFORESTATION WITH STAGGERED TRENCHES
PROTECTION AND GAP FILLING
NATURAL REGENERATION
GRASSLAND
ROAD
VILLAGE BOUNDARY



Appendix 8 *Thematic water resources development land map*

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